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EDITORIAL

Chemurgy and Strategy

CURTAILMENT of supplies of ethyl alcohol available for civilian use, due to its need for munitions manufacture, and the reflection of that same need in the sugar rationing plan, both suggest that we may have been misguided in judging the fuel alcohol question entirely by technical and economic criteria. We now would be in a more comfortable position, as a nation at war, if we had a large alcohol productive capacity which could be diverted on short notice from fuel to defense.

This writer never has been enthusiastic about alcohol simply as a source of Btu's, and still doubts that it can become economic on that basis. However, its known value for improving octane rating, and the possibility that its utility in improving the combustion characteristics of hydrocarbons might be further enhanced by chemical transformation or by combination with other substances, seem to deserve more serious study than has yet been conducted or even contemplated.

If this is to be the long war that military experts predict, with outcome dependent more and more on the weight of munitions that can be manufactured, we no doubt shall arrive at the problems of peace with a plant capacity for ethyl alcohol much greater than at present. Rather than close down the plants and charge off their cost, it would be desirable to have new uses for alcohol waiting to absorb its production. Looking toward that day, it seems logical to push research now in any direction that promises an economic market for alcohol. That market may be in the modification of engine fuels. It is a challenge to chemurgy.

WALTER B. JONES

Business Must Be *Better* than Usual

YOU can't borrow billions from bankrupts. Paupers pay no taxes. If this avowedly costly war is to be paid for, the buyers of bonds and the payers of taxes must be allowed to get hold of money — a lot of money.

And if, as predicted in high places, it is to be a long war, it must be financed more from current taxes and less from borrowings. We dare not blow the bond bubble until it bursts. Moreover, if they are right who describe bank borrowings as the paper pyramid whence cometh unlimited inflation, we had better borrow from private parties — and see that they have it to lend. National income must go up, not down.

High national income based on high prices and high wages is of itself inflation, nothing more. It multiplies the cost of war, speeds a nation toward collapse of its currency and the revolution which follows like thunderclap after lightning bolt.

High national income based on increased production at stable prices and wages is true wealth. Without peril to our economy or to our government it strengthens the sinews of war and lifts the standards of living. It meets the needs of the military without undue sacrifice by civilian. It softens, if it cannot prevent, the shocks of post-war adjustment.

In war, as in peace, the philosophy of scarcity is fallacy. The right answer always is to produce, not to do without. The profession which promotes production is engineering. While the politician subtracts and the demagogue divides, the engineer multiplies. Now, as never before, America needs more engineers, more engineering, more heed of its principles.—W. B. J.

War Duties for Ag Engineers

AN indication of the greatly increased demand upon agricultural engineers incident to the all-out war effort in which our country is now vigorously engaged, is contained in the following note received by the secretary of the A.S.A.E. from H. B. Walker, head of the agricultural engineering department, University of California:

"Our agricultural engineering staff is exceptionally busy with war duties. We have organized and are now carrying out over 200 farm machinery repair clinics. We have a bulk-handling job (grain) this year since our bag supply is needed by the army. We are also trying to reclaim bale ties to save metal. Dehydration is at the top in processing for both fruit and vegetables. Our machinery work is bearing fruit also. Perhaps our nearness to war operations increases our usefulness, but certainly agricultural engineering is needed here more than ever, and I assume the same conditions exist all over the country."

Another instance of new responsibilities that agricultural engineers are being asked to assume as a result of the war, is contained in a statement by V. S. Peterson, extension agricultural engineer of Pennsylvania State College:

"The big task . . . today is the dissemination of information on reconditioning of machinery to farmers and to men doing farm machinery service work. During the past two weeks we have received requests for over 500 meetings and demonstrations to be held before March 15th, and before the close of the crop production season the number will probably reach close to 1,000.

"Attendance at these meetings and demonstrations held during the past few weeks has averaged over fifty. Thus we will be reaching between 25 and 50 thousand farmers."

If we take Pennsylvania as an average state, and if we assume that 39 other states are doing the same thing, it means that somewhere between one million and two million farmers will be getting, during this coming season, special instruction and advice from agricultural engineers of the state agricultural extension services.

The Challenge

IN HIS first communication to the section members, J. H. Nicholson, newly elected chairman of the Tennessee State Section of A.S.A.E., commenting on the outlook for agricultural engineers for the year 1942, sums up the situation concisely and effectively as follows:

"To some of us it will mean taking up arms in the service of our country; to others the postponement of cherished projects; to all of us the sidetracking of our personal aims and ambitions for the BIG JOB, the successful prosecution of the war for the preservation of our national security.

"Upon agriculture rests the responsibility for increasing the production of food, clothing, and other sinews of war to meet the pressing needs of the military forces and civilian populations of our own country and of our allies. To meet this responsibility in the face of increasing shortages in men, machines, and materials it will require all of the ingenuity, mechanical skill, and organizational ability we as a nation are able to muster.

"Upon the shoulders of agricultural engineers rests much of the responsibility for implementing this gigantic effort. It represents the greatest opportunity in the history of our profession. It is a challenge we *must* meet."

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Conserving Soil and Water with Stubble Mulch

By Dr. H. H. Bennett

ABOUT eight years ago the program of the Soil Conservation Service got under way. From the beginning one cardinal principle dominated and guided its activities. Some called that principle idealistic and impracticable; others failed to grasp its significance.

That basic guiding principle was this: Adequate control of soil erosion on a farm, on a ranch, watershed, or any other land unit, requires the use and treatment of all the various kinds of land comprising that unit *in accordance with their individual needs and adaptabilities.*

Like any concise statement of a rule, this principle requires some qualification. First, the use and treatment accorded a parcel of land must be determined not only by its physical characteristics, but also by the available implements and methods of control and by the resources and preferences of the farmer himself. In other words, the treatment must fit not only the needs and adaptabilities of the *land* but the needs and adaptabilities of the *farmer* as well.

The second qualification of this general principle is that each distinct parcel of land to be treated must be considered in its relation to the next adjacent tract or to the entire unit area, the farm, the ranch, the watershed. The use and treatment of one area should, wherever possible, provide protection for adjacent areas. The management of lands on higher elevations should be determined in relation to downstream lands. Outlets for surface run-off should be located with proper consideration of adjoining lands. And, of course, the areas devoted to crops, grazing, and forest must fall within the pattern of a sound economic setup, or as near that as may be practicable.

The Soil Conservation Service has never deviated from this original concept. It has proved a practical and effective approach to the problem, and results generally have surpassed expectations.

To carry out a completely coordinated soil and water conservation program of this kind on a nation-wide basis requires the accumulation of a great deal of information for the blueprinting and planning of each farm and for execution of the job on the land. There are hundreds of different soils occupying varied slopes. These numerous varieties of land, occurring under a wide range of climatic conditions, are adapted to varied crops and cropping practices. From place to place, these differing conditions and uses result in varying susceptibilities to erosion.

It is almost safe to say that no two parcels of land are identical. Accordingly, each field — even each part of a field, pasture, or woodlot — requires its own particular set of conservation measures.

The conservationist has a choice of many different types of control measures for handling different types of problems. Unfortunately, effective conservation practices have not been developed for all the numerous problems and combinations of problems relating to the contrasting agricultural lands and practices of the nation. It is necessary, therefore, to seek constantly for cheaper, sounder, and more efficient ways of conserving our soil and water resources.

Soil conservation is probably the youngest of all the agricultural sciences. And so, from the very start, the work has been supported by a program of research through which new tools and methods of control and prevention are sought, and through which improvements on present techniques may be found. Soil conservation research has proved its value every step of the way.

In summarizing the progress of conservation to date, however, it seems to those of us who have been in intimate contact with the program all along, that the necessary average level of effectiveness, or efficiency, in the control and prevention work has not yet been attained. In some localities, results indicate that all that needs to be done has been accomplished. But for the country as a whole the work has been roughly rated by staff members of the ten regions of the Soil Conservation Service as ranging between 70 and 83 per cent effective in conserving soil and water.

Where good covers of dense vegetation and good stands of forest have been established, as on steep erodible land retired from cultivation, there seems to be no need for further protection. And where vegetative and mechanical conservation measures have been thoroughly joined and applied as part of a complete conservation treatment for the land, the results have averaged approximately 90 per cent in effectiveness

Paper presented December 3, 1941, at the fall meeting of the American Society of Agricultural Engineers at Chicago. Author: Chief, Soil Conservation Service, U. S. Department of Agriculture.

and often have approached pretty close to 100 per cent.

If present average effectiveness of conservation work lies somewhere between 70 and 83 per cent, then it is probable that in some localities the degree of success has hardly passed the halfway mark. That, of course, is not satisfactory, and, even though the situation may improve considerably as the various measures, such as crop rotations, have made their full contribution, higher levels of accomplishment must continue to be sought.

But more and more is being learned about control of erosion, conservation of rainfall, and better utilization of badly eroded land. A number of long strides forward have been made in this direction recently and other possibilities seem close at hand.

For example, the perennial lespedezas and kudzu have wrought profound changes in the use of much severely eroded land in many parts of the southern states. Lands which a little while ago were considered too poor or too steep to farm — even some areas that were so gullied they could not be plowed at all — are now producing excellent hay or grazing with these valuable crops. They are holding the soil, retarding run-off, reducing the effects of silting, and raising farm income. Many farms in the South are finally making headway toward diversification of crops and the raising of livestock as the result of the efforts towards soil conservation.

STUBBLE-MULCH METHOD EXPECTED TO INCREASE EFFICIENCY OF EROSION CONTROL PRACTICES

Just recently highly promising new methods and adaptations of older practices have been developed in certain localities for reducing losses of soil and rainfall by imitating Nature's way of keeping the ground clothed with a protective cover of vegetation or vegetative litter. Such surface material retards the scouring effect of both wind and water, prevents raindrops from striking the bare ground, and reduces evaporation.

This system or technique of utilizing the powerful protective effect of vegetative litter for controlling erosion, conserving rainfall, and reducing evaporation has been called the stubble-mulch method. It is expected to increase the efficiency of erosion-control practices over a large part of the country.

"Stubble mulch" is a technical term employed by conservationists to define that process of protecting cultivated or bare land in such a way as to conserve soil and soil moisture and reduce evaporation through the use of a complete or partial surface covering composed of some form of crop stubble or residue. The mulching material may consist of (1) that portion of the stubble of a preceding crop, as wheat straw or corn stalks, left standing on the ground, or partially incorporated with the soil; (2) that portion of the stubble or litter left lying on the ground after such operations as threshing or combining; or (3) such material as hay, straw, or other plant residues hauled in and spread over the ground. The method involves special tillage operations that do not turn the soil over. These usually fall under two main types, namely, subsurface tillage and stirring without inversion.

The primary function of stubble mulch, as already indicated, is to protect the surface from erosion by putting obstacles in the path of wind or water and to conserve moisture by favoring infiltration and reducing surface evaporation.

It is possible that various names may be needed to designate certain more or less distinctive phases of the stubble-mulch process, such, for example, as "straw mulch" (as wheat straw hauled in) and "standing mulch" (as soybean stubble left standing in fields as long as possible).

The stubble-mulch system of farming is the most promising conservation development in recent years. It has cut down erosion and run-off even more effectively than basin listing, which some conservationists have looked upon as the best way of holding soil and rainfall on the land, particularly in low rainfall areas. Basin listing *is* an excellent device for conservation of soil and water, especially where summer fallow is practiced or the land is left bare for any considerable period. Nevertheless the stubble-mulch system has demonstrated certain advantages over this method as well as over all other protective methods, except the permanent maintenance of dense cover of vegetation. Experience thus far indicates that the system provides a means of erosion control and water conservation which, alone or in combination with other measures, will prove 98 to 99 per cent effective or better, at least in some localities.

STUBBLE MULCHING IS A REVOLUTIONARY FARM PRACTICE AS ALL VEGETATION IS NOT PLOWED UNDER

The stubble-mulch system is a revolutionary farm practice in that it denies the customary method of plowing under all vegetation in preparing land for the next crop. Such practice exposes the unstable, freshly turned subsurface material to the chiseling effects of wind and rain. When rain strikes uncovered soil it becomes muddy water. When muddy water enters the small apertures of the soil, the suspended material filters out and seals or chokes the openings, so that more of the rainfall runs off the surface of the land rather than down into the soil. And more run-off usually means more soil erosion.

The stubble-mulching system is based on merely stirring the soil with plows that do not have moldboards to turn all the vegetation or vegetative litter under. It leaves a considerable part of the vegetable material — crop residue or vegetative litter — on the land as a surface protection against erosion. The practice has been extensively adopted in the wheat belt of the Pacific Northwest, where many farmers, instead of burning their wheat stubble, plow it so as to leave a substantial part on the surface to reduce the destructive impact of wind and water. Stubble mulching is being practiced on an increasing scale and with highly satisfactory results in parts of the Great Plains and to some extent in various other localities.

Farmers have been found who have practiced some form of stubble mulching for years. Agricultural scientists in various parts of the country and at various times have made some contribution to this practice. The Soil Conservation Service has examined these isolated experiences and tested various kinds of implements to be used with the practice as varied to fit different parts of the country. Farm machinery manufacturers, farmers, and soil conservationists have developed a number of subsurface tillage implements for the stubble-mulch operations employed in the Great Plains.

The powerful effect of a vegetative mulch in conserving soil and rainfall is strikingly illustrated by results obtained at the Statesville, N. C., soil and water conservation experiment station. Here, over a period of 3 years, one tract of land covered with a 2-in layer of undecomposed pine needles, and another tract covered with a layer of hardwood forest litter, lost as an average only 0.17 ton of soil per acre and 8.06 per cent of the total rainfall. However, a nearby area of the same soil and slope, cleared from original timber at the same time as the other two plots, but cultivated continuously to cotton, lost 32.26 tons of soil per acre and 16.13 per cent of the total rainfall during the same period. *(Continued on page 42)*

Machinery Requirements for Farming Through Crop Residues

By F. L. Duley and J. C. Russel

ABOUT four years ago the Office of Research of the Soil Conservation Service, in cooperation with the University of Nebraska, began studies on methods which it was hoped might lead to a more efficient use of rainfall and simultaneously reduce the disastrous effects of erosion.

These studies show that certain advantages in soil and moisture conservation can be gained through leaving crop-residue material on the surface of the soil, instead of plowing it under. These advantages are as follows:

1 An increase in capacity of soil to absorb water
2 Reduction of run-off
3 Reduction of water erosion and wind erosion
4 Reduction in rate of surface evaporation.

The ways in which residues on the surface aid in maintaining a high infiltration rate into the soil, the conditions under which they reduce evaporation, or the extent to which they prevent soil loss, conserve water, or increase crop yields as compared with conventional methods of farming, are subjects that have already been discussed in previous publications[1]. The particular objectives in this paper are to describe how farming has been done in our experiments, and to indicate how it can or should be done if residues are to be kept on the surface under practical field conditions. The emphasis here will be placed on implements and implement performance.

Agronomists, in carrying out their functions of soil and crop research, must use implements. In our case we employed the implements at hand and made changes, or sought other makes that could be modified more effectively. Implement companies through their executives and engineers have extended excellent and helpful cooperation. In turn, our activities have been open to their observation. As a result, there are now on the market a number of implements or attachments that can be used for thoroughly tilling the soil without burial of the residue. The working of soil beneath residues has been designated by us as "subsurface tillage", and the implements with which such work is done have been called "subsurface tillers".

Eventually there must be produced other implements, or attachments, for planting and tending crops through residues on the surface. Possibly also there should be some modifications in the machinery for harvesting crops so that residues can be returned to the land to the best advantage. All of these new developments are the province of the farm machinery engineers.

Subsurface Tillers. The agronomic requirements for tillage beneath residues are that the soil shall be well tilled but not necessarily inverted, and practically all residue, or as much of it as possible, shall be left on the surface. A subsurface tillage machine should operate through heavy residue or weeds without undue clogging. Only a minimum amount of the surface should be disturbed or trenched by the standards or shanks of the machine. So far, an implement to do all of these things with complete satisfaction has not been perfected. However, there are now available several machines that approach these requirements sufficiently that careful farmers can do an acceptable job of subsurface tillage after they have learned the principles of correct operation. This latter point is of vital importance in practically all of the machines.

The various subtillage machines that are now available may be classified into three groups, with respect to the type of cutting equipment used, as follows: (1) V-shaped sweeps, (2) straight blades, and (3) attachments for rod weeders.

Subsurface Tillers with V-shaped Sweeps. Figs. 1 to 4 illustrate some of the variations of the first type. The widths of most of the sweeps now in use vary from 22 to 45 in, although some wider ones have been used. The angle of the "V" usually varies from 60 to about 90 deg.

In the operation of V-sweep tillers, the sweeps are run perfectly flat. Penetration is obtained through the suction of the point and the pitch of the blade, and to a certain extent through the weight of the machine. The sweeps should be strongly built and have sufficient pitch to give the soil enough "throw" to pulverize it. The shanks to which the sweeps are attached should be strong, but not thick enough to cause furrowing of the soil.

This furrowing can be reduced further by the use of rolling coulters. As the coulter slits the soil, the V nose of the sweep spreads this kerf, allowing the shank room to pass through, and then the opening closes. However, if the shanks are too thick to clear the kerf, they catch trash and soil and thus make trenches.

The notable advantages of V-shaped sweeps is the ease with which they cut through and shed roots without becoming fouled, and their adaptability to operation at comparatively shallow depths. With sharp sweeps we have successfully subtilled through sweet clover and old stands of alfalfa.

Most of the V-sweep type tillers now available have been made through attachments to and modifications of already existing machines. The possibility of transforming existing equipment in such manner that it can be used for subsurface tillage should greatly simplify the change from our present system of plowing residues under to that of leaving these materials on the surface for protection.

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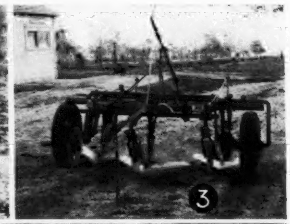
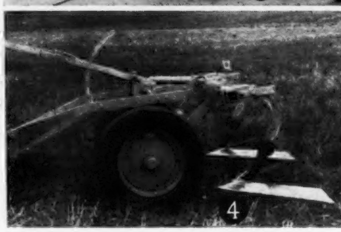
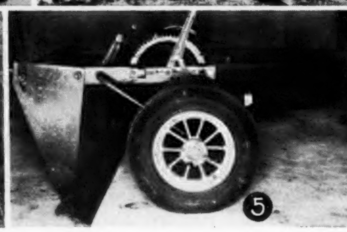
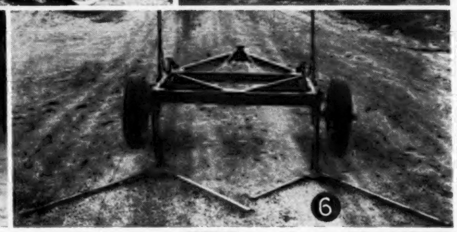
Subsurface Tillers with Straight Blades. Fig. 5 illustrates a subsurface tillage implement with a straight blade which is drawn at right angles to the direction of travel. The blades on machines of this type vary from about 5 to 11 ft, but some wider ones have been built.

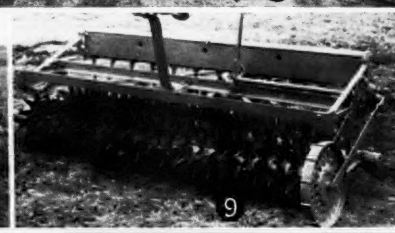
Straight blades do not shed the roots or trash as well as blades that operate at an angle. Consequently, implements of the straight-blade type must be run at somewhat greater depths than is necessary with V-sweep machines, particularly where ground is loose or uneven. The tendency

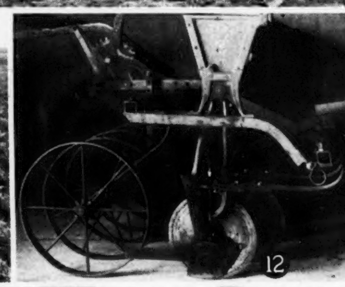












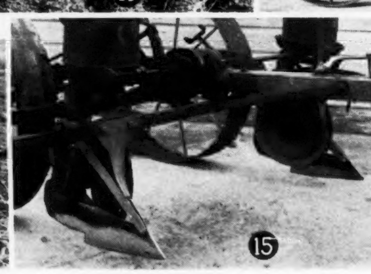


Fig. 1 A 5-ft, horse-drawn implement used in plot work, the first machine to be designated as a "subsurface tiller." More commonly available in 5, 8, or 12-ft sizes with tractor hitch, power lift, and standard rubber-tired wheels • Fig. 2 A subsurface tiller made by attaching 24-in sweeps to standard tool-bar equipment. The heavy iron bar suspended ahead of the rolling coulters facilitates clearance in dense weeds • Fig. 3 A 7-ft subsurface tiller made by attaching 32-in sweeps to the lister shanks of a standard tool-bar machine • Fig. 4 A 7-ft subsurface tiller made by attaching two 45-in sweeps to the beams of a two-row lister. Overlap is obtained by using different angles of attachment of sweeps to shanks • Fig. 5 A straight-blade type of subsurface tiller • Fig. 6 The straight blade of this machine has been replaced with wide V sweeps for subtilling at shallow depths after previous deep subtillage • Fig. 7 A subsurface tillage attachment to a 9-ft rod weeder. The points facilitate penetration, and the revolving rod clears the machine of trash • Fig. 8 Two 7-ft implements for packing soil beneath a covering of residues. The prongs of the wheels enter the ground in the reverse direction of a rotary hoe. This type of implement has been designated as a "treader" • Fig. 9 Treader with seeder box attached for seeding alfalfa, clover, and some grasses through residues • Fig. 10 A 10-in, semideep-furrow drill operating through subsurface-tilled land • Fig. 11 Subtilled land in southwestern Nebraska drilled to winter wheat with 12-in (left) and 14-in (right) deep-furrow disk drills. The seedbed was prepared with a subsurface tillage attachment on a rod weeder • Fig. 12 Press-wheel wheat drill equipped with flat coulters and narrow shoes. Note the specially constructed wings attached to the shoes for holding straw out of the row until the wheel passes • Fig. 13 Grain drill and treader hitched in tandem • Fig. 14 Two-row stalk cutter operating through three tons per acre of sorghum residues. Subtillage followed this operation very satisfactorily • Fig. 15 Corn planter equipped with 10-in disk-furrow openers and stub runners. One disk has been removed to show attachment of bracket and shield which eliminates clogging. With this equipment row crops can be planted through heavy residues without difficulty • Fig. 16 A pivot-axle cultivator equipped with 21-in sweeps and rolling coulter shields

of trash to hang on the standards cannot be overcome so effectively by the use of rolling coulters, as is possible with the V-sweep type machines, since the straight blade does not open the kerf made by the coulter.

Since this type of machine has not been consistently suited to loose, sandy land, or to shallow operation after the first time over, one manufacturer has devised a new type of sweep attachment shown in Fig. 6. These sweeps do not have sharp edges, but are made of a single plate of steel bent back on itself with the rounded edge in front. These sweeps have been found to do good work at shallow depths after the land has been subtilled once at a greater depth with either the straight blade or some other type of machine.

Attachments for Rod Weeders. The third type of subtillage machine is the toothed bar attachment for the rod weeder. One type of this tool is shown in Fig. 7. These small shovels are attached to a bar beneath the revolving rod. They penetrate stubble land readily to depths required for subsurface tillage, and the revolving rod clears the machine of residue. Such clogging as occurs with this type of machine seems to occur almost entirely on the standards and is not due to collecting on the small shovels. Rolling coulters are not very effective in preventing the accumulation of trash on the shanks, but perform much the same as on the straight-blade machine.

These attachments for rod weeders are particularly well adapted to weeding and pulverizing the soil after one deep subtillage has been given. The rod weeder, even without the attachment, is proving to be a very valuable tool for later tillage operations after the first subtillage has been done with the attachment in place or with some other type of tiller.

Packers. As the use of subsurface tillers has developed, it has become more and more evident that these implements do not always leave the soil in satisfactory condition for planting or seeding. The tiller may leave the land too loose in some cases, or too cloddy in others, or the residues may be uneven or bunched. Just as a disk or harrow may be needed after plowing, it is often desirable to follow the tiller with a smoothing or packing operation. Where packing alone is needed, almost any type of roller or sprocket type packer may be used. To accomplish a smoothing and packing job at the same operation, the implement shown in Fig. 8 has been used. This implement is a rotary hoe except that the wheels have been reversed so that the points enter the soil opposite the conventional direction.

This equipment we have designated as a "treader". It tends to tear apart large clods, pack the soil from below, and does much to distribute but does not cover the residue. The machine does not clog, even when run through the heaviest residue, provided the residue is reasonably dry. Corn or sorghum stubs sometimes stick between the prongs of the wheels, especially if the ground is slightly moist.

Another valuable feature of this implement is its action on weeds after they have been cut loose from the subsoil with a subsurface tiller. The treader pulls out small weeds, or uproots larger ones that have been cut off below the surface. In this way it serves as a very effective supplementary machine to the subsurface tiller. It is often possible to kill weeds or volunteer more effectively by this combination of machines than by the use of the subsurface tiller alone.

Another important use of this implement is to tread down dry stalks and weeds, particularly such bushy weeds as the Russian thistle. If these materials are dry and crisp, they feed through the interlocking wheels without clogging, and in the process they are thoroughly torn and shattered. Thus they are converted into valuable protective material, and in addition all later operations are facilitated.

The features of the machine shown in Fig. 8 that seem to make it highly effective as a treader, are the mountings of the axles and the clearance below the frame. The axle housings are at the extreme ends, and there are no mountings in the middle. The frame is high enough above the wheels to give sufficient clearance to avoid clogging.

By attaching a seeder box and drivewheel, as shown in Fig. 9, this treader has been converted into a broadcast seeder for planting such crops as alfalfa and sweet clover beneath a protective covering of residue. The seed is broadcast ahead of the front gang of wheels and is treaded into the ground as the implement passes. In order to avoid too deep seeding, it is well to go over the land once or twice with the packer before the seed is distributed. With this method good stands of alfalfa and sweet clover have been obtained on seedbeds prepared by subsurface tillage and with residues sufficient to prevent serious erosion by either wind or water while the crops were becoming established.

Small Grain Production. The production of small grains under a system where residues are left on the surface involves two sets of questions, namely, seedbed preparation and seeding. The implements of seedbed preparation, that is, subsurface tillers and treaders, already have been adequately discussed. The remaining question is how seeding through residues is to be accomplished.

Where land has been summer fallowed, much of the residues on the surface will have decayed by seeding time, and drilling can be done without any alteration of conventional equipment. Where grain is seeded in the fall following another small grain crop, or in the spring following a row crop, the ordinary drilling machinery as a rule is not successful.

The conventional 7 or 8-in spacings of the common disk drills are too narrow for heavy residues to escape without clogging. The 10-in, semideep-furrow drills with heavy press wheels have fair clearance, but much of the valuable residue is buried (Fig. 10), and some may be thrown into the row and mixed with the seed. The 12 and 14-in, deep-furrow drills bury the residues to a considerable extent (Fig. 11).

Satisfactory drilling has been done through either light or heavy residues with the equipment shown in Fig. 12. This is a low-down, press-wheel type drill with single flat disks, like the coulters of a plow, set at a very slight angle and with a simple shoe alongside that makes only a narrow furrow for placement of the seed. Spaced 10 or 12 in apart, these flat disks cut cleanly through the residue with a minimum of clogging. To insure adequate pressure against any particular cutter, a bar has been bolted across and slightly above the line of disks, so that when the drill runs into a bunch of heavy residue, the whole weight of the machine is thrown on the cutters affected, thus forcing them through. Since the cutters are flat, they have no great pitching action. However, there is a slight tendency for trash to fall back under the press wheels. This has been obviated by the attachment of a wing to each shoe which holds the residue aside until the press wheels pass. Fig. 13 shows this drill in operation coupled behind a treader.

So far it has been assumed in our work that a clean, narrow furrow in which to drill the seed, with a relatively wide space on which residue can be maintained between the rows, for protection against wind and water erosion, is the most desirable method for using residue with small grain.

Row Crop Production. As in the case of small grain, the preparation of the seedbed for row crops has been

accomplished by going over the land first with a subtiller, and then usually with a treader. In most cases it has been necessary to subtill the land at least twice for corn, and three times for sorghum, before planting. In the case of stalk land, the stalks have been cut before subtilling is done (Fig. 14), mainly to facilitate planting and cultivation.

The planting of row crops has been done by means of an ordinary corn planter equipped with 10-in disk-furrow openers and stub runners (Fig. 15). Special braces have been put in place of the usual brackets at the ends of the runners to lift the residue and move it up against the disks, where it is divided. Thus equipped the planter will pass through heavy residue without clogging. The type of furrow made by the 10-in disks is such as to make cultivation of the corn easily accomplished and effective.

The cultivation has been done by means of 21-in sweeps attached to the beams of a single-row cultivator. The sweeps were so adjusted at the first cultivation that the side thrust from the V-shaped sweeps pushed enough soil into the furrow to cover the weeds in the row without covering the plants (Fig. 16). In order to prevent too much soil from falling into the row, rolling coulter shields have been used. These can be so adjusted vertically or horizontally that any desired amount of soil can be put to the plants. The rolling shields have a big advantage over other types, when working through residues, in that they cut their way through and keep themselves clean without clogging or dragging any residue.

In case wet weather delays the first or second cultivation, and weeds get started in the row, it has been necessary to use concave disks in place of the rolling coulters. These disks were adjusted to throw the soil away from the plants, taking most of the weeds out of the row. The sweeps then pushed the soil back toward the plants, and thus practically all the weeds in the row were either cut or buried.

At the last cultivation it has sometimes been necessary to throw enough soil toward the row to give a slight ridge in order to cover all weeds. To do this, wings have been attached to the sweeps which tend to curl the soil in toward the plants.

Conserving Soil and Water with Stubble Mulch

(Continued from page 38)

Investigations at Lincoln, Nebr., record that when two tons of wheat straw were applied per acre and plowing was done with a blade or winged implement a few inches beneath the surface, without turning the straw under, 54 per cent of the rainfall was conserved. Under comparable or duplicate conditions, only *20.7 per cent* of the rainfall was conserved with ordinary summer-fallow. With basin listing, only *27.7 per cent* was conserved.

The results with basin listing, carried on in connection with the Lincoln studies, are of particular interest because there was virtually no run-off from land treated in this way, yet the amount of water conserved during the season was only about one-half as much as was stored under a mulch of straw. This emphasizes the fact that prevention of run-off is not the full solution of the moisture problem on the Great Plains. On the basin-listed plot the losses due to evaporation from the convoluted bare surface tended to offset the gains due to prevention of run-off. Basin listing did prevent water erosion, but this was also true where the straw treatments were used. And the straw, by acting as a mulch, had the important added advantage of reducing evaporation losses.

Recent experiments at Clemson, S. C., have shown that a mulch of oat straw or crimson clover hay almost eliminated erosion and run-off in the tests made on each of the four different soil types. Where the mulch was applied to corn grown on Madison clay loam (June 1940) at the rate of 2½ tons per acre, the results were as follows: Without mulch, 800 lb of soil lost per acre and 56 per cent of the precipitation from a rain of 1.28 in in late August; with oat-straw mulch, 15 lb of soil lost and 1.5 per cent of the precipitation; with crimson clover hay 11 lb of soil lost and 0.9 per cent of the precipitation.

The run-off from rains on the other soils tested showed the same trends as in this instance.

For several years M. E. Gowder has been practicing a type of agriculture in conformity with the findings of the research work referred to above. He operates a small farm in a part of the hilly Piedmont section near Gainesville, Ga., where erosion has been exceedingly severe and costly to farmers. Few farms are unaffected. Over large districts virtually every cultivated acre has suffered and thousands of acres have been made unfit for cultivation.

Mr. Gowder never plows under crop residues; rather, he plows through them without turning the soil over, so as to leave on the surface as much as possible of all stubble — corn stalks, cotton stalks, the litter of cowpeas, or whatever he grows. Even when the land was cleared, the leaves and twigs of the forest floor were plowed through, not under. A narrow plow without a moldboard — a "scooter" type of plow — is used for this type of cultivation, going down to a depth of about one foot. In addition to preserving crop residues, Mr. Gowder uses terraces and cultivates on the contour. As a result, the soil suffers practically no erosion. Yields are much better — around three times better — than the average for the locality.

STUBBLE-MULCH PRACTICE MAY MAKE TURNING PLOW OBSOLETE IN SOME LOCALITIES

It now seems entirely possible, if the stubble-mulch practice continues to spread and to produce such desirable results as indicated, that the old type of turning plow (or cover-up plow) may pass out of general use in many localities. There would, of course, still be a place for this implement, as for building terraces and for pasture contour furrowing and contour listing. The passing of the turning plow for field cultivation would be an historical event in agriculture — in the progress of conservation particularly.

The stubble-mulch method for soil and water conservation is not suggested as a cure-all, but as a specially efficient tool of proved value for many localities, and of good promise for all localities subject to impoverishing soil erosion.

On many farms it is going to be necessary to use various measures for control of erosion and conservation of rainfall, such as installations of soil-conserving and water-control structures and practices, as well as changes in land use, in order to complete the job. And, in this connection, it is important to observe that it may not be practicable to complete the application of all measures at once; but the farm should be planned with that end in view and all needed measures, practices, and structures should be established coordinately and as quickly as practicable.

With the comprehensive type of complete land treatment now being used to help the farmers and ranchers of America, it is believed that the rate of accelerated erosion eventually can be reduced to the point where it is no faster than the rate of normal erosion. And this, of course, is the goal that must be attained if our farm land is to endure.

A Study of Subsurface Tiller Blades

By L. W. Chase

CHARTER MEMBER A.S.A.E.

BEFORE opening this discussion on the design of subsurface tillers or right-side-up tillage machines, I have one question to ask, to which the scientists and experimenters should give careful thought, namely, Why the modern disk and moldboard plow? Haven't we accepted them as a fact without giving thought to their need?

I have been told that loose soil holds no more available moisture than the normal compact soil. Undecayed vegetation mixed with the soil temporarily increases moisture evaporation. Loose soil erodes much faster both by wind and water than compact soil. In my opinion vegetation and weed seeds are destroyed by the elements much quicker on the surface than within the soil. It is at least a partial, if not a complete fallacy that the ground is plowed to give the plant roots a better opportunity to develop. We plow about 5 in deep for winter wheat and $3\frac{1}{2}$ to 4 in deep for spring grains. The roots of fall sown grains penetrate the soil to a depth of about 4 ft and spring sown about 3 ft. Plowing for corn is generally about 5 in deep and all the roots in the upper 4 in of the soil are killed by later cultivations.

Isn't it a fact that we have been plowing our ground for years, with the possible exception of preparation for root crops, just to kill vegetation growing at the time, and to prepare the soil for easier seeding and future cultivations. At the same time we have augmented wind and water erosion, evaporation, and removed noxious weed seeds from the elements and birds which might destroy them.

I don't contend that subsurface tillage in its present state of development will supercede the plow, but I believe it to be the beginning of a great change in tillage and farming methods. It is new, and the best and most thorough work should be advocated by educators.

Some four or five years ago my son and myself had heard something of Dr. Duley's laboratory tests of covering soil with burlap and straw, whereby he was able to prevent the minute semi-impervious layer of soil from forming on the surface during the early stages of rains. We had also heard that he had planted some corn and covered the soil between the rows with various amounts of straw in order that he might make field tests. We gave the matter very little thought as it is common practice in our section to mulch potatoes and many of the smaller fruits in this manner. However, one day in early summer Dr. Duley came to our office and stated he had been able to conserve considerable more moisture in his straw-covered plots than in the bare ones, but the weeds were now growing quite profusely and he wondered if we had or knew of any machine or device that would cut off the weeds and not disturb the straw. The request seemed so ridiculous to me that I jokingly replied that I had a good sharp spade and file at home which he might go out and get, and then go to China and start digging up from below and he might eventually get the weeds without disturbing the straw.

However, my son suggested that possibly a bindweed exterminator sweep which we had developed, might help solve the problem, so we made a set of sweeps modified after our bindweed exterminator but designed for better penetration and entering the ground through straw. These were attached to a one-row cultivator frame. While Drs. Duley and Russel were trying out these sweeps on experimental plots, we were working to perfect their design for field use. As far as I know, these were the first plows or tillers made purposely for tilling the ground beneath a mulch and leaving all the mulch on the surface.

Before entering into a discussion of the design of a subsurface tiller, we should first consider what is to be accomplished by such an implement and field conditions in which the work is to be done.

A perfect subsurface-tilled field will have from $1\frac{1}{2}$ to $2\frac{1}{2}$ tons of vegetable residue, none of which is coarser than coarse straw, scattered uniformly over each acre. The surface soil should be slightly loosened and cut loose from the subsoil at a depth such that shoots will not start from the cut ends of severed roots, yet shallow enough so the plants above the cut line will not continue to grow. There should be no wheel marks, ruts, trenches, or vertical kerfs left in the field. This is very important, but as yet it has not been perfectly accomplished by any design to our knowledge.

The field conditions that have come under our observations are as follows:

1 Loose straw hauled in and scattered over a plowed or disked field

2 Mellow soils covered with stubble

Paper presented December 3, 1941, at the fall meeting of the American Society of Agricultural Engineers at Chicago. Author: President, Chase Plow Co.

(Left) This field of weeds has been subsurface tilled, leaving no ruts, trenches or vertical kerfs • (Right) This stubble with the straw from the combine spread over the field, has been subsurface tilled. Chase subsurface tillers are shown in each picture

3 Mellow soils with stubble intermixed with straw spread by a straw spreader from a combine. This condition is the nearest to an ideal field for good subsurface tillage

4 Mellow soils with stubble and straw left in windrows from the combine

5 Mellow soils with stubble and weeds from 6 to 10 in high and with or without straw.

Of the above five field conditions, No. 1 is impracticable because of the cost, except for experimental work and intensive farming on hilly ground. No. 2 will produce fair results in ordinary stubble, but better results if the stubble is from 12 to 18 in high. Conditions such as No. 2 with long stubble to No. 5, inclusive, are the most perfect for subsurface tillage; however, it is much better to use a straw spreader on a combine and the weeds should not be allowed to get over 10 in high. It is believed — and tests have partially proven it — that if the weeds get higher than this, they will remove more moisture from the soil than subsurface tillage will conserve. Hence, the only value, except economy of operation, of this tillage method when weeds get too tall is the retarding of erosion.

In the 100 to 150 fields in which I have had an opportunity to work with subsurface tillers, probably there were not over a half dozen that would come under the conditions I have listed.

Push soils were encountered. Soils so hard that plows would not work at all or not do over a 25 per cent job. Soils with about 3 in of loose dirt on top and a very hard subsoil. Fields densely covered with all kinds of weeds, bindweed, morning-glories, wild pig weed, Russian thistles, kochias, sweet clover, lodged grain, dense masses of volunteer wheat, etc. These conditions existed, partially because of idle acres but more because the farmers did not know what subsurface tillage really was, or what to expect of the machine or when to use it.

It is my opinion that machines made of the materials now at hand, which will satisfy the farmer under the last-named conditions, will not do a satisfactory job under conditions such as should and may exist for subsurface tilling if proper management is practiced.

Ideally, subsurface tillage consists of severing a layer of soil from the surface of the field, stirring this layer somewhat and leaving no ruts, trenches, wheel marks, or vertical grooves or kerfs. The only implement that I can imagine for accomplishing this is a narrow band of steel, probably 1½ in wide extending laterally across the field with its front edge sharp, its upper surface polished, its rear edge raised about ½ in, and with no attachments for pulling or pushing it.

Try to imagine a field which is perfectly bare, that is, the surface is free from all vegetation, and let such a blade pass through. You would hardly be able to detect that the field had been worked. The soil would not have been moved horizontally, there would be no ruts, grooves, or vertical kerfs. In fact, it is doubtful, unless you stepped on to the field that you could tell that it had been tilled.

Imagine this same blade passing through a field of stubble with the straw from the combine intermixed. It would be impossible except upon careful inspection to tell that the field had been tilled. Yet it has been, and still the stubble stands erect to catch the snow, and to hold the loose straw in place to make a cover to prevent erosion during rains and winds and retard evaporation during sunny and windy periods.

Again imagine this same stubble field covered with weeds such as exist in most fields just after harvest, and let the imaginary blade pass through. Now you have the roots of the weeds severed so they will not draw moisture from the subsoil, and their foliage has been added to the surface mulch.

As I understand it, the foregoing is the ideal subsurface tillage. The question is how to accomplish it.

It is imperative that ruts, trenches, and vertical kerfs be eliminated as much as possible. There are just as many tracks, except in contour farming, up and down hills as there are around them. In spite of the mulch these ruts up and down hills will carry off water, and the larger the ruts, the poorer the coverage and the greater the run-off.

When designing farm machinery to be sold in quantities, there are two points the manufacturer must keep foremost in mind, and these are the determining factors. First, the machine must be one the farmers will buy regardless of whether it is one he should buy. Second, it must be a machine that can be manufactured and sold at a profit.

Also, in the designing of all farm machinery the design is limited to the type of material available, its strength, the range in which the machine can work or the operator act, and the conditions under which the machine must perform. Probably in 90 per cent of designing the problem is to choose the lesser or least of evils or the best or better of ideas, none of which are perfect, and the best designer is the one who has an uncanny way of determining what design will take best with the farmers.

In some early work with bindweed eradication machinery, C. W. Smith of the University of Nebraska tried extending a rather heavy blade laterally across the lower ends of a two-row lister's beams. Because the draft of this device was so excessive, the blade had to be so wide and thick, the shanks which propelled it so massive, and there was so much annoyance with tins, wire, and other foreign

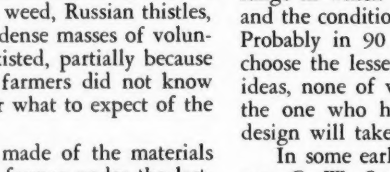


FIG. 1

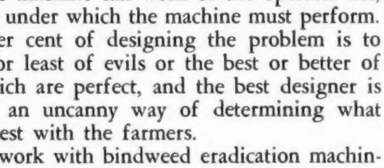


FIG. 2

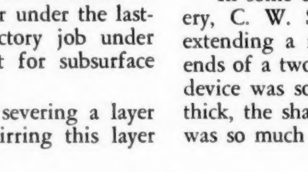


FIG. 3

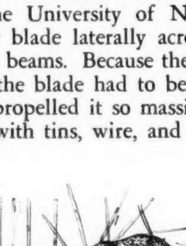


FIG. 4

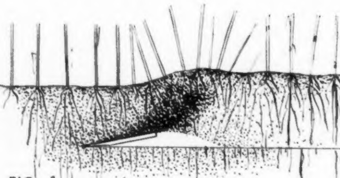


FIG. 5

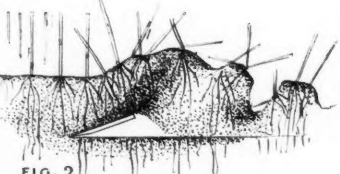
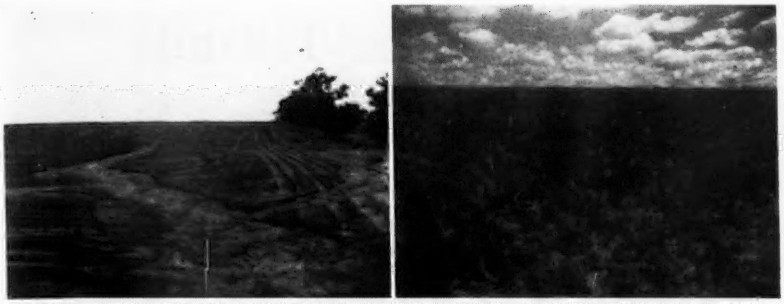


FIG. 6



The pictures of these two fields, about 3 mi apart, were taken following an exceedingly heavy rainfall. The bare field, with a slope of about 2½ per cent, shows excessive run-off. The other field, with about 3 per cent slope, was previously subsurface tilled and no run-off resulted

substances catching on the edge of the blade, we did not consider it would be a commercial success. However, I understand there is a Canadian company which has developed one of this type that is being marketed.

Because it was impossible to get the ideal strip of steel through the soil without some means of propulsion, we selected the typical cultivator shank method attached at the center of the cutting blade or sweep, and since most manufacturers have followed this practice, the discussion that follows will be based on this design.

Actions of Soil in Passing Over Blade. If the blade is flat, it will slip through the soil disturbing it or the vegetation very little, as shown by Fig. 1, but if the angle of the blade to the horizontal is too great, so much resistance to the movement of the earth over the blade is set up that the soil and trash jam together and cause not only a mixing of the mass but an uneven distribution on the fixed soil, and entirely too often a complete clogging of the gang of tillers (Fig. 2).

On our bindweed sweeps we gave the pitch of the blades 1-1/16 in in 4 in and on our first tiller sweeps about the same. We are now using 1-3/16 in in 4 in. At one time we tried a set with a pitch of 1⅜ in in 4 in, and in the first field we used them, we found the condition shown by Fig. 2. Of course this condition would not obtain in all fields, but it would exist too often in fields being subsurface tilled at the proper time.

Sweeps were also tried with the bevel side up and the same pitch for the body of the blade. We found this gave better penetration in hard ground, but also introduced a scouring problem in many fields and especially when the ground had to be tilled the second time soon after the first. Just at the rear of the break between the bend and the body of the blade is an area of reduced pressure (Fig. 3), and unless the soil is in a very dry condition, it will adhere at this point and eventually cause choking. It was our experience also that such sweeps required sharpening more often, and blacksmiths had much more difficulty in sharpening them. In fact, every set of sweeps we have seen drawn out by hammering on top has been ruined, while we have never seen a sweep ruined by hammering on the under side.

Angle of the Blade. Since it is not practical to use a sweep with blades at right angles to the line of travel, the problem is to find what angle is the best. We have experimented with a half dozen angles, but only placed three on the market.

With an angle of 50 deg our bindweed exterminator sweeps would do the best job of cutting weeds and subsurface tilling and cover more acres without sharpening, but they would not enter trash or hard ground unless they were dropped into a furrow when started. This eliminated their commercial possibilities as a tiller. The next ones we put on the market had an angle of 39 deg. These would probably be the most perfect ones we have marketed, if the farmers would use them at the right time, that is, follow immediately behind the harvester. There is one exception to this, and that is in the nigger wool or blackroot country. These roots are so tough that plow shares will not cut through them. Hence for a share of any kind to work in this area, it must have sufficient slope so the blackroot will slide along the edge and off the heel.

Because of this condition we were compelled to design a sweep which had a smaller angle, 32 deg. It was impossible to do this without also increasing the pitch. With a greater pitch, the sweep has better penetration in hard ground but does not do as good work in the mellow soils.

Suction. So far we have been unable to design a machine in which the sweeps can be given adjustable suction. If the blades could be made with their cutting edge at or nearly at right angles to the line of travel, this would be easy. The suction must all be in the pitch of the blades, and the blades must run flat, the reason for which may be seen in Fig. 5. Here is a sweep running flat at about 4 in depth, and it strikes a weed with a tap root about 3 in from the end. The blade is down where the soil is firm and the root is severed. Say that we tip the sweep down so the blade has ¼ in more pitch. This will cause the heel of the sweep to run about 1½ in higher than the point, and we will have the latter up in the softer soil and the condition illustrated by Fig. 6. The root slips around the end of the blade. Someone may suggest letting the point of the sweep run deeper when it is tipped up for more suction. Sweeps must have overlap, and to have overlap they must be offset; that is, every other one is set ahead. This offset varies from 7½ in in some machines to 24 in in others, and in the average machine will cause the points of the front sweeps to run about 3 in deeper than the heels of the rear.

It is possible to put a suction adjustment in each line of sweeps so they would run at a uniform depth, but the condition as shown by Fig. 6 would still exist and complicated mechanism of doubtful value would be added.

Furthermore, sweeps running on their points wear very fast. It has been reported to us that on one farm the new sweeps were run on their points and had to be sharpened when about 40 acres had been covered. After being sharpened they were run flat, and the farmer had covered over 200 acres and they were still working satisfactorily.

Overlap and Offset. The overlap of the blades and the offset of the sweeps go hand in hand. To get all the weeds the offset should be as little as possible and yet get the maximum usable overlap of the blades. Our bindweed exterminator sweeps had 3 in overlap, and we never knew of their skipping a weed. However, we did experience scouring trouble on the rear sweep. When we put out our first tillers, we gave the blades 1½-in overlap, and with only a 7½-in offset received *(Continued on page 50)*

Equipment for Subsurface Tillage

By H. A. Morehead

OUR experience with machines for subsurface tillage is confined to Nebraska conditions where there is a wide variation in types of soil, from blow sand to the heaviest gumbo, although most of the soil is a heavy clay. There is also great variation in the amount of moisture available during the growing season; for example, there is a considerable area where the water level is very low and rainfall is light, while on river bottom lands there is plenty of water available from the subsoil. It is interesting to note that these varying soil and moisture conditions are found in an area covering only about 17 Nebraska counties.

Subsurface tillage tools should be used in Nebraska very soon after the binder or combine, at which time double duty is obtained from them. The surface of the soil is loosened up, thereby cutting down evaporation and stopping weed growth to a large extent. The straw and root growth keeps the soil from blowing, and it is in ideal condition to absorb the rainfall and lessen erosion from water run-off. So for certain parts of our territory this practice is ideal, providing the subsurface tillage tool is used at the right time. However, too many farmers are doing this work too late in the season, after the weed growth is 2 to 3 ft high; therefore, this heavy growth saps the soil of its moisture.

The subsurface tillage tool, as we know it, is an all-purpose machine. That is, it is being used for summer fallow work, bindweed eradication, and, in many cases, in place of the disk harrow.

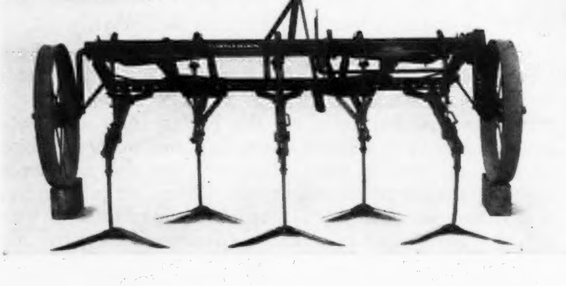
In my opinion the surface mulching program should be tried experimentally in all localities before it is recommended too strongly. It is a local problem, and I believe in recommending only such farm practices as the average farmer can and will follow after he has been shown. Varying soil and crop conditions must be handled by different practices. I do not believe, at this time, that we can handle a wet gumbo soil by using a surface mulch, because this soil dries out very slowly in the spring, and in an average rainfall year this ground must be farmed when it is still too wet, as far as average farm practice is concerned.

In the past farmers have burned the straw or corn stalks to get the ground clear of trash so it will dry out in time for seeding, although it is becoming a practice to follow the combine by plowing under the small grain straw. This practice helps to loosen the tough gumbo soil so it is easier to plow and list, as this soil is deficient in humus. All corn is listed in this type of soil.

In this day of mechanized farming, we will have a big selling job on our hands if we recommend a new and different system of farming. In fact, we must be able to show the farmer that his returns will be greater over a period of time; and we must also be able to furnish him equipment to do the work in the recommended way, without extra labor being involved, and in most cases with even less man labor being required. (I am not worried about the machines to do the work.) I am sure the farm equipment industry will be able to furnish the machines, after the present emergency, and when we find out, by experimental work over a period of years, what practices we should recommend in each locality.

In the accompanying pictures is shown experimental equipment that is being tried *(Continued on page 64)*

Paper presented December 3, 1941, at the fall meeting of the American Society of Agricultural Engineers at Chicago. Author: Omaha Branch, International Harvester Co.



These pictures show three different machines of the International Harvester Company equipped with that company's experimental subsurface tillage equipment. Fig. 1 (upper left) is an HM-46 lister, while Fig. 2 (above) shows a wheatland lister — both tools equipped with special subsurface tillage sweeps. Fig. 3 (lower left) is a regular field cultivator with the subsurface tillage equipment

Horsepower Requirements of Power Take-off Driven Combines

By C. G. E. Downing

THE POWER take-off combine has, for the past ten years, been considered a standard harvesting implement. There are at present two distinct types of this machine, namely, the conventional type having a wide cutting bar with a narrow cylinder and body and the high-speed type having approximately the same width of cylinder, body, and cutting bar. Both have a number of followers, each of whose machines are quite different in construction. One feature common to all is the direct drive from the power take-off of the tractor through the tractor clutch. However, the amount of power transmitted through the power take-off to operate the threshing mechanism of these machines in the field has been, at least to my knowledge, an unknown quantity. Thus recommendations as to the correct size of tractor required to operate these machines under various conditions have been an assumption based primarily on field observations and manufacturers' ratings.

The growing popularity of the power take-off machine, with its diversity of designs, has brought an increased number of requests from farmers for definite information regarding tractor sizes and speeds to operate the machines correctly, especially where they are to be operated on rolling land.

Extensive testing and experimental work has been carried on at the Dominion Experimental Station at Swift Current, Saskatchewan, Canada, during the past harvesting season, to secure information on two types of combines. The work was conducted over a wide range of field and crop conditions, including light and heavy crops, rolling and level land with soft to hard footing conditions. Therefore, information applicable to average farming conditions in many districts has been acquired from which a basis for tractor recommendations for the power take-off combines may be set up. This paper has been prepared to show the procedure and results of this test work, together with a comparison of the two types of combines used.

The conventional type of combine used in the test work had an 8-ft width of cut and a 24-in rasp type rub bar cylinder. It was equipped entirely with roller chain drives, except a steel link chain reel drive, and a V-belt drive to the shoe and straw walkers. The machine was mounted on two rubber-tired wheels and had a weight of 3512 lb. The high-speed type combine used had a $5\frac{1}{2}$-ft width of cut and a 5-ft rubber-faced, angle-iron type cylinder. It was equipped with all V-belt drives, excepting two short steel link chains. The reel was ground driven. This combine was also mounted on two rubber-tired wheels and had a total weight of 2730 lb. One tractor was used for all combine tests, thus eliminating any variation in power output which would arise had different tractors been used on each machine. The tractor used had four operating speeds and was capable of developing a maximum of 30 bhp.

A special vacuum-gage horsepower recorder which was developed at the Dominion Experimental Station at Swift Current, was attached to the engine and used to record the horsepower developed by the tractor. (The development of this recorder constituted preliminary work in the preparation of a master's thesis by the author.) One trip was first made around a field with the combine mechanism in operation. The gage would record the power required to propel the tractor and combine and to operate the combine for the particular crop and field condition. A second trip was made around the field without the combine mechanism in operation. In this case the gage would only record the power required to propel the tractor and combine. The difference between the two power recordings indicates the power necessary, in this particular crop, to operate the threshing mechanism through the power take-off. This set of tests was run with each combine at all of the four working speeds of the tractor in all crop and field conditions encountered.

The results of this work show a number of interesting and unexpected characteristics of the two machines. First, in a 30-bu per acre crop, which is average, the power required to operate the combine mechanism and the power required to propel this particular tractor and combine is approximately the same on level land irrespective of the speed of travel. On rolling land in identical crop conditions up to twice the amount of power is necessary to pro-

Paper presented before the American Society of Agricultural Engineers at its fall meeting at Chicago, December 1941. Author: Agricultural engineer, Dominion Experimental Station, Swift Current, Sask. (Canada).

Fig. 1 (Left) The conventional type of combine used in the tests described by Mr. Downing was a Massey-Harris machine, generously loaned by the local company branch. It is designated in the charts as M-H8ft. • Fig. 2 (Right) The high-speed type combine used was an Allis-Chalmers machine, and this machine is designated in the accompanying charts as A-C$5\frac{1}{2}$ft.

pel the tractor and combine as to operate the combine mechanisms irrespective of the speed of travel as the grade is increased up to 15 per cent. Also, one and one-half the power is necessary to combine a 40-bu per acre crop as is required to combine a 5-bu per acre one, irrespective of speed of travel on level land. This definitely reveals the need of a flexible system of tractor size recommendations if these machines are to be operated over even this range of field and crop conditions. Second, the power required to operate the threshing mechanism of both machines through the power take-off is approximately the same over the average working range, that is, over the range of 20 to 30-bu per acre crops. In view of the fact that the conventional type machine had an 8-ft cut compared to the 5½-ft cut of the high-speed machine, the power consumption per foot of width is definitely in favor of the conventional machine. Third, this difference in power of the two machines varies somewhat over the complete range of operating conditions. At the no-load limit, over twice the horsepower per foot of width is required by the high-speed machine; whereas at the 40-bu per acre load limit, a maximum in this study, the horsepower required is only about one and one-third times that of the conventional type.

This wide spread of initial horsepower and the gradual convergence as the load is increased, may be due primarily to one of two major features in design or to an accumulation of them all. First, there is the probability that the difference is due mainly to the cylinder designs. That is, the long 5-ft cylinder, although quite light in construction, requires the extra horsepower on no load due to its larger cylindrical area. However, with its greater capacity it is better able to handle a larger volume of material. Second, there is a possibility that this spread may be partly due to the use of roller chains on the conventional machine and the V-belt drives on the high-speed machine. There is obviously a power loss in the V-belt drives as shown by the heat of the sheaves and the belt. It is possible that this loss is not proportional to the load on the machine, thus showing a large spread at no load and a decreasing spread as the load is increased. The roller chain drives may also become hot under load, especially if the correct tension is not maintained. These two features, namely, cylinder design and roller chain versus V-belt drives, are suggested as possible answers for this power discrepancy. They are features which may easily be experimented with in more detail. It will be necessary, however, to check with machines not quite so extreme in design.

THE RESULTS INDICATED IN THE GRAPHS SHOW THE DIFFERENCES BETWEEN THE TWO COMBINES

The results as prepared for this paper are shown in the form of graphs rather than in tables. The graphs show more clearly the differences between the two combines of the effects of speed, heaviness of crop, and power requirements when operating on rolling land. The term "bushels per acre" is used as a measure for heaviness of crop. An upper yield limit of 40 bu per acre has been used on the charts. This is considered a heavy crop in the test area but by no means a maximum. The speed of travel in each operating gear of the tractor was checked as the average speed over the length of the field. It is to be noted that in the accompanying charts the speeds are indicated according to the tractor gear used. The following average field speed values correspond to the tractor gears:

First gear — 2.60 miles per hour
Second gear — 3.45 miles per hour
Third gear — 4.50 miles per hour
Fourth gear — 5.29 miles per hour

The tractor used throughout the tests on both machines was an International Harvester Company standard W-6. The comparison of these two combines as undertaken in this paper is strictly from a horsepower requirement basis in the harvesting of spring wheat crops. Any other merits which either of these machines may possess in regard to this or any other crop are not considered in this paper.

Fig. 3 shows the amount of horsepower transmitted through the power take-off to operate the threshing mechanisms of the two machines at the four operating tractor speeds and under the various crop conditions. Note that in the average crop range, from 20 to 30 bu per acre, the power requirement of the two machines is approximately the same.

Fig. 4 is derived from Fig. 3 showing the horsepower per foot of width to operate the combine through the power take-off. Note the large initial spread of power at the no-load point and the gradual convergence of each pair of lines, according to gear, as the load is increased.

HORSEPOWER REQUIRED TO DRIVE COMBINE MECHANISM DEPENDS ON AMOUNT OF CROP HANDLED

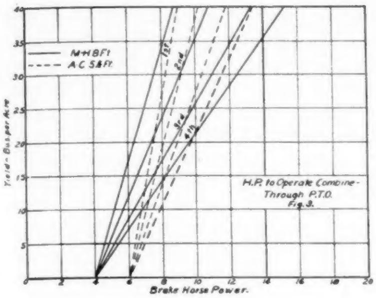
Fig. 5 shows the horsepower required to operate the combines through the power take-off on a total-weight-of-crops-through-the-cylinder basis. "Pounds of crop" includes the total weight of straw and chaff as weighed from the rear of the machine, together with the weight of grain delivered to the tank. The horsepower required to drive the combine mechanism depends only on the pounds of crop per minute through the cylinder. The rate of feeding depends of course on crop yield and ground speed. For example, a 34-bu per acre crop in first gear and a 14-bu per acre crop in fourth gear will each feed to the cylinder (of the M-H8ft machine) at the rate of 150 lb per min and require the same horsepower.

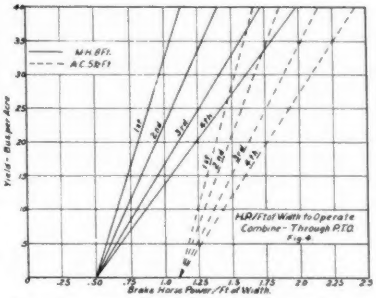
Fig. 6 places the machines on a per foot of width basis giving the clearest and most comparative conception of the horsepower consumption relationship.

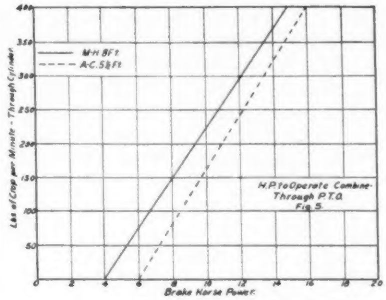
The relative amount of straw and grain put through a machine will vary in every district in different years depending on crop conditions. Fig. 7 shows mainly the correlation between the amounts of grain and straw for this particular season's crop. It shows that by weight almost as much straw as grain was threshed. I believe this is a higher percentage of straw than is usually handled, which would mean that the power requirements, as shown according to crop grain yields, are somewhat high.

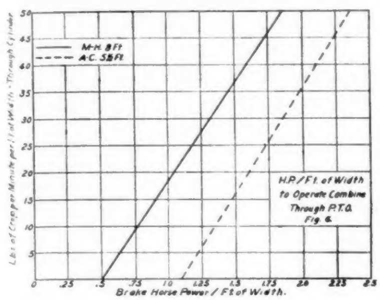
The power required to propel the same combine and the tractor which is used to operate it is shown in Fig. 8 at various speeds and in the three footing conditions encountered in this test work. The heavier machine (M-H8ft) shows a relatively lighter draft on the hard ground due to lighter running bearings or the larger size of wheels. When the footing becomes soft, the draft is increased almost to a par with the lighter, small wheeled machine (A-C5½ft). In the graphs referred to in the following paragraphs, the medium stubble land footing condition only is considered.

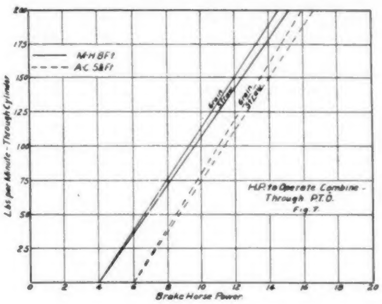
Fig. 9 illustrates the power necessary to propel the tractor and combine on various grades at each of the four operating speeds. The horsepower required by the M-H8ft machine is less than the A-C5½ft on level land, but the draft (of the M-H8ft machine) increases more rapidly as the grade increases, being indicated in the figure by a more rapid increase in horsepower. This is in accordance with expectations and theoretical calculations considering the greater weight of the M-H8ft machine. The total horsepower of the tractor is shown to be reached in propelling the tractor and combine in third gear on a 20 per cent grade and in fourth gear on a 15 per cent grade.

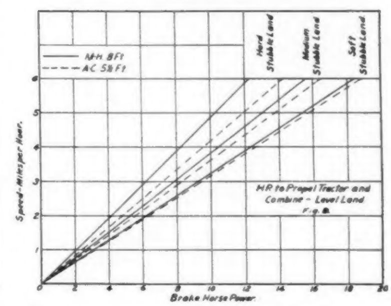


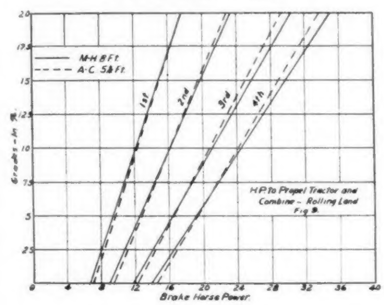


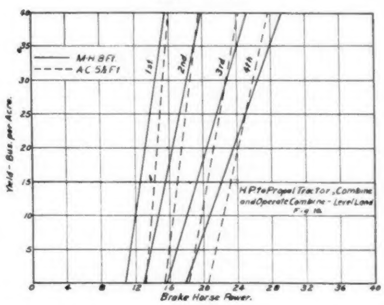


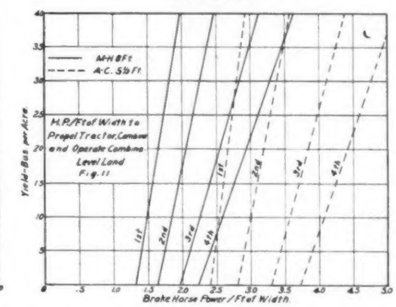










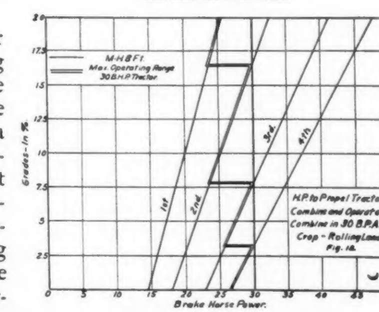


The total power necessary to propel the tractor and combine and to operate the combine is the main consideration in actual field operations and is shown in Fig. 10. This shows the ideal condition in combining, that is, operation on level land. Note the power necessary for both machines is practically the same over the average range of crop conditions. At the slower speeds a smaller tractor could operate the machines quite satisfactorily. This would tend to reduce the total horsepower necessary as less would be needed to propel the smaller tractor itself. Thus a shift of the first and second graphs of the figure toward the left could be made to fit the case of smaller tractors.

From the standpoint of practical application in wheat harvesting, Fig. 11 has been devised to show the total horsepower per foot of width required by the two machines. This definitely shows a difference in favour of the conventional type of machine.

Although the operation of the combine on level land is the ideal condition, the more practical one is operation on rolling land, especially in this area. Fig. 12 shows the exceptionally high total horsepower requirements necessary if speed of travel is to be maintained on various grades. An idea of the number of gear changes necessary while operating in a 30-bu per acre crop on a field with varying degrees of slope may be realized by tracing out the double line in the figure. This represents the maximum operating range of the 30-bhp tractor used.

The combine mechanism, as mentioned previously, is directly driven through the tractor clutch. This means that both the tractor and the threshing mechanism must be started at the same time. There is a lapse of time between the instant the clutch is engaged and the tractor and threshing mechanism have reached their operating speed. During



this time lapse the crop passing through the machine is not properly threshed. There is also a further loss when the threshing mechanism is slowing down after the clutch has been disengaged. The time lost waiting for the threshing mechanism to come to a complete stop before being able to shift the tractor gears, especially when operating on rolling land, is quite noticeable. It is usually necessary to shift to a lower gear than is required for field operation due to extra torque needed to overcome the momentum in bringing both the tractor and combine to operating speed. These are two significant losses giving sufficient reason to indicate the pressing need for some type of overrunning clutch or separate clutch for the power take-off as standard equipment if these machines are to be operated economically on rolling land. With such an addition to the power unit the combine could be brought up to operating speed before

the crop was put through it. Also, it would permit the changing of tractor gears to either a faster or slower speed without materially changing the combine's operating speed.

The psychological effect on the operator should also be considered. Suppose nearing the top of a hill there was a slight increase in grade or the crop was a little heavier. Would the average operator not try to struggle to the top in the same gear even though his tractor was overloaded and slowed down to where it was not properly threshing rather than stop, lose a minute or two, and then probably have to travel two gears slower? Would he not be more likely to shift to a lower gear before he hit this extra variation, if it could be done without stopping and losing time? Most certainly it would result in a more efficient job of threshing.

In summarizing, I would like to emphasize that the main purpose of the work undertaken was to gain information on the horsepower requirements of power take-off combines. From this information, a basis for tractor size and speed recommendations could be set up for power take-off combines under any particular operating condition.

A comparison of these two types of combines, quite different in design, each with a number of followers, definitely shows a marked difference in power consumption on an equal operating basis in favour of the conventional type. An indication is given as to possible design features which may cause these power variations.

The horsepower values shown in the graphs, although only the results of one year's field operations, are indicative of what might be expected in any season. It is common knowledge that the relative amounts of grain and straw contained in a crop vary in different years, but they are not so extreme that the results as shown might not be considered an average for present guidance and for comparison with future work.

Lastly, it is clearly indicated from the results of these tests that some type of independent power take-off clutch is essential on the combine or on the tractor unit if satisfactory operation of this type of combine is to be secured under rolling land conditions.

A Study of Subsurface Tiller Blades

(Continued from page 45)

many complaints about weed skipping. Another lot was run through with 2 in overlap and less complaint about weed skipping and no scouring trouble. Our last run had 2½ in overlap, and I do not recall a complaint of weed skipping, but we have received two scouring complaints. This leads us to believe that 2½ in is the maximum overlap.

Strength of materials limits the distance apart the shanks may be placed. The greater the offset in the sweeps, the more freely excessive trash will pass through. However, since overlap is limited, the more weeds will be skipped. No machine is free from lateral surging. This may be caused by unevenness in the surface of the ground or unevenness in the texture of the soil, and all machines must run in other than straight lines. From this it will be seen that the greater the offset the more uncut weeds will slip around the ends of the blades.

Shanks. The shanks which propel the sweeps are very important. They make the kerf or trench, and a shank should be designed to make the narrowest possible kerf and gather the least amount of roots and trash.

A shank has to have enough material in it to pull or push the sweep and to hold it in position laterally. A thin and deep shank will make a smaller kerf. At the same time, it will break the trash at such sharp angles that it will adhere more firmly, and because of the depth of the shank, the trash cannot roll around and fall off as easily.

A wide shank can be made shallower, but it in turn will make a wider kerf and will hold more soil on its face which in turn will hold weeds. A shank which is arched back will have more strength for its cross section and will let the trash move back so there is not so much danger of clogging the machine. It should also be so carefully proportioned with respect to the strength of the sweep blade that it will spring or even bend before the blade breaks when hitting some firm object. The shank can be reset, but a broken blade can only be repaired with a new one.

Independently Hung or Fixed Sweeps. There already seem to be two lines of thought relative to sweep suspension. One is to have each sweep suspended semi-independently of the others, and the other is to have them all fixed rigidly to one frame.

For the following reasons we believe in the independent sweeps: The shank can be made lighter, as it only controls one sweep. There will be less breakage of blades for the beam and shank will spring and give without moving the whole gang of sweeps and the frame of the machine. One sweep may choke and rise out of the ground without raising the whole machine. There is also lighter draft.

Other designers no doubt claim for their machines simplicity of design and better penetration for a large proportion of the weight of the entire machine is on each sweep.

ALL SUBSURFACE TILLERS SHOULD USE COULTERS AND THE NOTCHED ONES ARE PREFERABLE

Volunteer Wheat. Volunteer wheat and weeds which grow in similar mats form a problem which has not been solved. If this vegetation has been tilled at the proper time, it is easily destroyed. However, farmers have not yet learned how to handle it, and as a result the wheat sod is nearly always formed before tilling takes place. The sweeps will then not break it up sufficiently so it will die. We have tried rods attached to the sweeps with rear ends bent up, dragging chains behind the sweeps and Drs. Duley and Russel have tried heavy ropes with large knots. The results obtained were not satisfactory.

All subsurface tillers should use coulters. Notched ones are preferable, and if possible they should be streamlined.

Rocks. How to design a machine to work satisfactorily in rocks is a problem we have not solved. Yet we have given it more thought than any other detail of the machine during the past two years.

Spring trips will work very satisfactorily if the sweeps hit the rocks anywhere near their middle, but they will hit the rocks on their wings as often as in their central section. Hitting a rock at the wing part of the sweep throws such a wind or twist into the spring-trip mechanism that it fails to function. If the shanks are made strong enough to resist bending, a trench will be left behind them and the sweeps will break. If the sweeps are made heavy enough to withstand the shock, it will be practically impossible to keep them sharp. So far we have decided that the independent beam, with a semispring steel standard and a flexible beam with a spring trip is the most satisfactory.

Time permits me to discuss only the tillage elements of the subsurface tiller. Suffice it to say that when farmers have learned when and how to handle their lands with the machines now on the market, they will get very satisfactory results. However, I believe that the ultimate machine will contain new sections of much better steel than is now used and will cost about twice as much.

Response of Insects to Color, Intensity, and Distribution of Light

By H. L. Gui, L. C. Porter, and G. F. Prideaux
FELLOW A.S.A.E. MEMBER A.S.A.E.

THAT CERTAIN insects are attracted to light is common knowledge. Many attempts have been made to apply this phenomenon to the control of insect pests, but with varying degrees of effectiveness. It is easy to see the wide field of application the use of lights might have in reducing the insect nuisance from homes, gardens, and lawns, to say nothing of open air concessions, pleasure resorts, roadside stands, and the like.

The work reported in this paper was undertaken to determine which colors and what method of application would alleviate the insect nuisance to the greatest extent. The work has been carried through as a cooperative project with the department of entomology of the Ohio Agricultural Experiment Station and General Electric Company's engineering department at Cleveland, Ohio. The authors acknowledge the assistance of J. S. Houser, chief of the department of entomology, Ohio Agricultural Experiment Station. The photographs herein reproduced are the works of either Harry Bineau, photographer at the Ohio station, or R. H. Tesreau, photographer of General Electric Co.

A rather comprehensive study of the effect of light waves on insects has been made by Weiss, et al[1] in the laboratory. An application of some of their findings has been made. A discussion of the work done in 1940 has been published by Porter[2].

Lighting Terminology. Since there may be some confusion by those not thoroughly familiar with lighting terminology, the following definitions are offered:

1 Candlepower — luminous intensity expressed in terms of the intensity of one standard candle.

2 Foot-candle — the illumination on a surface at 1 ft distance from one standard candle.

3 Level of illumination — number of foot-candles at any particular location.

4 Brightness — luminous intensity of any surface in a given direction per unit of projected area of the surface viewed from that direction.

5 Lumen — the unit of luminous flux or the amount of light on 1 sq ft of area, all points of which are 1 ft distance from one standard candle.

Methods and Materials. When this project was started in 1940, a rather simple setup was used for comparing the different colored lamps. It consisted of exposing the lights simultaneously and continuously from dark in the evening until after daylight within opal glass traps, which, in general appearance, resemble a low-priced kitchen ceiling fixture, but differs in having three apertures approximately $\frac{3}{4}$x2 in in size in the periphery. The edges of these apertures were turned inward to make entry easy and exit difficult for the insects. These traps will be referred to as the "Miller" traps. A metal bottom, held in place by springs, made removal of the insects easy. The arrangement of these lights in Wooster and at Nela Park in 1940 is shown in Figs. 1 and 2. The heat generated by the light within the trap served as the lethal agent to kill the insects that entered.

Certain disadvantages of the setup used in 1940 were recognized. When all lights were exposed simultaneously, there was a constant intermingling of the light from the various traps. This mixing of light might possibly cause the insects in the illuminated area to act entirely differently from the way they would had they been exposed to a single light from a single source. In 1940 lamps were first tested at equal wattage; then lamps were selected of such candlepower as to give approximately equal brightness to the globes, though the bulb brightnesses as seen through the apertures were not equal nor were the wattages, and consequently the temperatures inside of the globes.

In order to eliminate these difficulties, a change in the setup was made in 1941. During this year only two colors were compared at the same time. The comparison was accomplished by using pairs of the Miller traps, and with each an automatic time switch which would change from one color to another at 30-min intervals throughout the night. In the later tests, lamps were used which were of equal candlepower, bulb brightness, and wattage. This

Paper presented before the fall meeting of the American Society of Agricultural Engineers at Chicago, December 1941. Authors: Respectively, assistant entomologist, Ohio Agricultural Experiment Station, and illuminating engineers, General Electric Co.

[1]Weiss, Harry B., Soraci, Frank A., and McCoy Jr., E. E. Notes on the reaction of certain insects to different wavelengths of light. Journal of the New York Entomological Society 49:1-20-41. Additional notes on the behavior of certain insects to different wavelengths of light. Journal of the New York Entomological Society 49:149-155 (1941).

[2]Porter, L. C., General Electric Review, 44:310-313, June 1941.

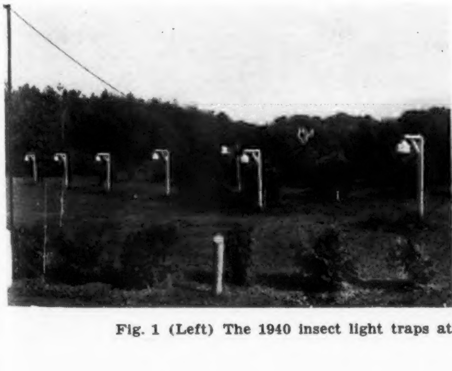
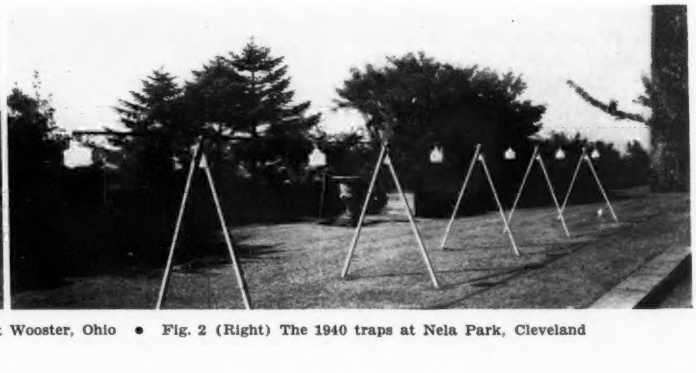
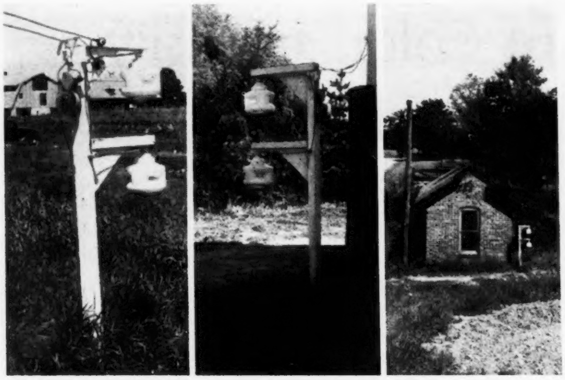



Fig. 1 (Left) The 1940 insect light traps at Wooster, Ohio • Fig. 2 (Right) The 1940 traps at Nela Park, Cleveland



Insect traps at Wooster, Ohio: Fig. 3 (left) Station A • Fig. 4 (center) Station B • Fig. 5 (right) Station C

Three trap locations: Fig. 6 (left) At Nela Park, Cleveland, Ohio • Fig. 7 (center) At Mentor Harbor, Ohio • Fig. 8 (right) At 16259 Oakhill Road, Cleveland Heights, Ohio

arrangement resulted in equal globe brightnesses, though they were somewhat lower than the bulb brightness. Three pairs of traps were operated at Wooster (Figs. 3, 4, 5), and one pair at each of the following addresses: Nela Park, Cleveland (Fig. 6); Mentor Harbor, Ohio (Fig. 7), and 16259 Oakhill Road, Cleveland Heights (Fig. 8). These photos show the type of surrounding vegetation at each test location.

At Wooster the insects were removed from the traps and the number of insects determined almost every day, but at other places the catches were allowed to accumulate for several days. When the number of insects was not too large, an individual count was made. Large catches were screened through a 3/16-in mesh sieve, and the insects remaining on top were counted. Those passing through were weighed to 1 mg, and a small sample was removed from the mass with a spatula. This sample was weighed and counted, and, by proportion, the number of small insects was determined. The total number of insects was determined by adding the counted number of large insects to the calculated number of small ones.

Certain tests were made in which the Miller trap was not applicable. In those tests, Tanglefoot flypaper, either in strips or squares, was used. The flypaper was used in several different ways; therefore, a description of each setup is deferred until each is discussed.

Work Done in 1940. Although the work done in 1940, while inconclusive, does indicate certain trends; the work was exceedingly valuable in that it tested many of the procedures and made possible the collecting of much data of a reliable character during the following season.

The 1940 setup at Wooster consisted of six Miller traps, using the colors yellow, amber orange, red, flame tint, natural amber, and white. At the start of the season, 100-w lamps were used in each trap, but later they were changed to include one each of the following lamps: 50-w white, 75-w yellow, 75-w natural amber, 100-w flame tint, and 150-w amber orange. Lamps of these wattages were chosen because they were the lamps which most nearly produced equal globe brightness (2.7 cp per sq in) according to measurements made at Nela Park. The brightness of the globes was determined by actual measurement in the laboratory with globes equipped with 100-w lamps of different colors. Since the lumen outputs of lamps

TABLE 1. NUMBER AND WEIGHT OF INSECTS COLLECTED AT LIGHTS OF VARIOUS COLORS WHEN EQUAL-WATTAGE LAMPS (100-w) WERE USED

COLOR OF LIGHT		Yellow		Amber-orange		Red		Flame-tint		Natural Amber		White	
INSECTS	Total No.	No	Wt (mg)	No.	Wt (mg)	No.	Wt (mg)	No.	Wt (mg)	No.	Wt (mg)	No.	Wt (mg)
Chironomidae Little midges which can go through porch screens. Very few bite but are quite bothersome	2946	69	4.5	2	0.1	21	1.8	153	11.1	186	10.3	2515	118.2
Culicidae Mosquitoes	10	2	0.1	1	0.1			2	0.2	2	0.4	3	0.6
Tipulidae Crane flies	19			1	0.2	2	1.3	10	6.0			6	2.5
Helomyzidae	44	1	0.1	4	0.5			2	0.3			37	7.9
Drosophilidae Fruit flies which collect in considerable numbers on over-ripe fruit, both indoors and out	19			4	1.0			2	0.2	2	0.2	11	1.4
Lonchopteridae Minute black flies often found on windows	19	1	0.1					1	0.2			17	4.6
Phoridae	3	1	0.0							2	0.5		
Mycetophilidae Fungus gnats	258			258	11.8								
Cordyluridae	2									2	0.5		
Cecidomyiidae Gall gnats	1									1	0.0		
Total *Diptera*	3321	74	4.8	270	13.7	23	3.1	170	18.0	195	11.9	2589	135.2
Noctuidae	34	8	112.4	10	39.0	3	88.4	4	25.9	4	78.6	5	90.6
Arctiidae Tiger moths	9					1	4.6	2	35.7			6	113.5
Geometridae Adult stage of measuring worms	15	1	4.0	3	18.0			2	12.7	2	18.4	7	25.6
Pyralidae	23			1	0.8	3	14.7	6	28.2	3	8.8	10	71.5
Notodontidae	1			1	3.0								
Olethreutidae	8											8	30.6
Microfrenatae	23			5	2.6	4	2.6			1	0.8	13	13.0
Total *Lepidoptera*	113	9	116.4	20	63.4	11	110.3	14	102.5	10	106.6	49	344.8
Braconidae-Hymenoptera Wasp-like parasites which are beneficial	152	12	3.9	21	6.1	2	1.7	19	6.3	16	4.7	82	27.5
Miridae-Hemiptera Sucking plant bugs	7			1	0.1					2	1.3	4	2.1
Cicadellidae-Homoptera Leaf hoppers, injurious to plants	92	4	1.0	11	2.9	4	1.0	8	1.5	5	1.2	60	14.6
Neuroptera Lacewing fly, beneficial but not important	1			1	0.6								
Trichoptera Caddice flies, not harmful but a nuisance pest	1					1	0.5						
Total in Samples	3687	99	126.1	324	86.8	41	116.6	211	128.3	228	125.7	2784	524.2

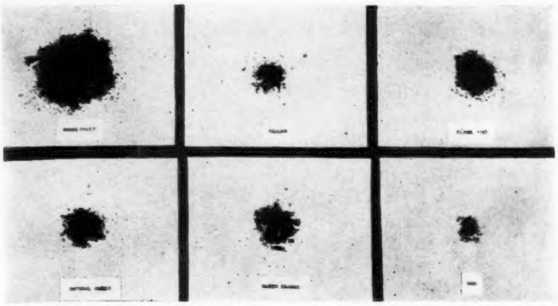


Fig. 9 Insects caught at Nela Park, August 12-18, 1940. Weight as follows: Inside frost (white), 1.3 gm; yellow, 0.3 gm; flame tint, 0.4 gm; natural amber, 0.2 gm; amber orange, 0.3 gm; red, 0.1 gm

of the same colors but different wattages were known, it was easy to determine what the globe brightnesses would be, as they would vary in direct proportion to the lumen output of the lamps. Red has little value in the illuminating field although it is known to be very low in its attractiveness to insects (Fig. 9). Blue also is not a practical color for most work purposes, but it is exceedingly attractive to insects (Fig. 10).

The data taken in 1940 consisted of weighing the insects caught in each trap each morning. However, to quote Mr. Porter[2], "it is questionable whether the weight of insects caught is a satisfactory measure of their relative nuisance. For example, several hundred little gnats might be considerably more of a pest than a single June bug, but the latter might weigh more than all of the former. Also, the relative weights may vary depending upon whether they are taken soon after the insects are caught or after they have dried out.

"To correlate some of these factors, the following procedure was carried out. The average weight of all insects caught by each color at Wooster between August 12 and 31 was determined. Then the night's catch coming nearest to that average (August 23) was selected as typical. The catch for that night was taken to Ohio State University. There the insects attracted by each color were counted, classified, and weighed under the direction of Prof. D. M. DeLong. The results are shown in Table 1.

"In this table the first group, known as *Diptera,* includes insects of the fly classification. Many of them are considered harmless to plants and animals, but their presence may be very annoying. The remaining group embraces several orders of insects, many of which are injurious to vegetable and fruit crops in at least one stage of their development.

"The data in the table clearly show differences dependent on what criterion is used, that is, whether the weight or the number of the insects. On the weight basis the amber orange lamp caught the least, but on the number basis the minimum catch was made by the red lamp.

"It was found impractical to correlate the weight of insects with the number caught because the unit weight varies greatly among species, and the species captured in turn vary with weather conditions, season of the year, etc."

75-w Yellow vs. 60-w White. In the 1941 tests the 75-w yellow lamp was selected as our standard of comparison because it is of a popular wattage for outdoor use. The 60-w white lamp was selected because it is of higher brightness and nearest wattage of any standard lamp available. Its brightness and candlepower were reduced in certain instances to that of the yellow lamp by spraying with opal white.

Toward the latter part of the tests, there was evidence that temperature inside of the trap had some bearing on the insect kill, and, consequently, on the count. Measurements showed that there was only 5 F (degrees Fahrenheit) difference in temperatures inside the traps equipped with 60 or 75-w lamps. It was felt that this little difference would have a negligible effect on the number of insects

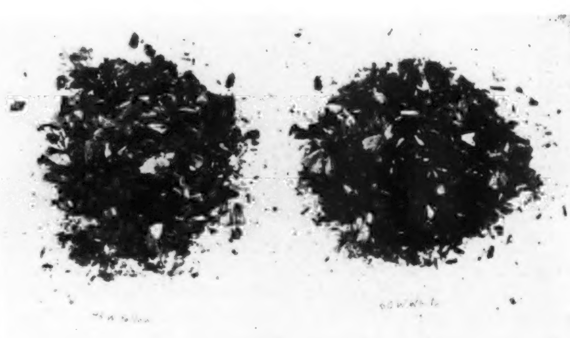


Fig. 10 (Upper left) Ten-night catch by 100-w inside-frosted tungsten filament lamp (left) and by 100-w AH4 mercury arc lamp (right) • Fig. 11 (Upper right) Total catch by 75-w yellow and 60-w white lamps (See Tables 2 to 5 for actual counts) • Fig. 12 (Lower left) Relative catches of 75-w yellow and white lamps of equal candlepower and equal bulb brightness • Fig. 13 (Lower right) Relative catches of 15-w inside frosted lamp plus 60 w of heat from a black bulb emitting no light (left) and of 75-w yellow lamp (right)

caught. Since it is a well-established fact that 120 F is generally sufficient to kill insects in a relatively short period, and since the 60-w lamp produced such a temperature in the traps, it was felt sufficient for the purpose. In tests described later in this paper where much lower wattage lamps were used, means of equalizing the temperatures were introduced.

Yellow and white lamps of approximately equal brightness, obtained by using 75-w yellow and 60-w white lamps, were used in the Miller traps in four localities in 1941. The 75-w yellow and the 60-w white bulbs produced globe brightnesses of calculated values of 1.67 and 1.62, respectively. The results of the tests made at Wooster are given in Table 2.

TABLE 2. NUMBER OF INSECTS TRAPPED AT WOOSTER, OHIO

	60-w white lamp				75-w yellow lamp			
	Station				Station			
Date	A	B	C	M	A	B	C	M
7/1	144	615	874	544	149	933	488	523
7/2	107	1392	3	501	130	331	74	178
7/3	18	19	1	13	33	22	47	34
7/4	86	141	—	114	52	57	—	55
7/15	137	598	876	537	99	191	163	151
7/16	30	1053	1097	727	104	463	646	404
7/17	48	53	62	54	48	65	34	49
7/18	7	16	9	32	2	14	6	7
M per day	72	483	432		77	260	208	

It will be noted that, with one exception, the mean catch per trap was greater when the white lamps were used than with the yellow. The daily average also was greater for the white lamp at two out of three stations.

At Nela Park, where a single pair of traps was used, a similar situation is shown as indicated by Table 3. However, in this locality the differences were small.

TABLE 3. NUMBER OF INSECTS TRAPPED AT NELA PARK, CLEVELAND, OHIO

Date	60-w white lamp	75-w yellow lamp
6/20-21-22/41	393	460
6/23	20	25
6/24	65	84
6/25	72	123
6/26	213	212
6/27	148	132
6/28-29	103	180
7/2	31	21
7/3-4-5 6	335	97
7/14-15	392	182
7/16-20	329	287
M per day	111	95

TABLE 4. NUMBER OF INSECTS TRAPPED AT 16259 OAKHILL ROAD, CLEVELAND HEIGHTS, OHIO

Date	60-w white lamp	75-w yellow lamp
6/20-30	19,669	13,999
7/1-6	4,158	2,790
7/13-20	3,011	2,158
M per day	1,032	729

TABLE 5. NUMBER OF INSECTS TRAPPED AT MENTOR HARBOR, OHIO

Date	60-w white lamp	75-w yellow lamp
7/2	3,355	1,442
7/3	1,688	434
7/4-5	421	1,013
8/6-9	280	264
M per day	718	394

Data collected at 16259 Oakhill Road, Cleveland Heights, and at Mentor Harbor indicate the same relationship (Tables 4 and 5). At each of these places a single pair of traps was used. The total catches at all test stations for 60 vs. 75-w lamps were 42,062 and 28,054, respectively, and are shown in Fig. 11; the yellow reduced the insect nuisance 33.3 per cent.

75-w Yellow vs. 75-w White. In order to eliminate as many variables as possible, particularly the temperature within the traps, 75-w lamps having equal brightness and candlepower were prepared in the laboratory at Nela Park for this test. (As regularly manufactured, an inside-frosted lamp of a given wattage will produce approximately one-half again as much brightness as a yellow lamp of the same wattage.) In order to determine whether color or heat was the determining factor in the relative attractivity of yellow and white lamps, tests were made with 75-w lamps of both colors, but the white lamps were coated with a white material to the degree that candlepower and brightness were equal to the yellow. The exact colors of these lamps as located on the International Commission on Illumination color coordinate basis are as follows:

Yellow	*White*	
x = .5607	x = .4666	Charts 1 and 2.
y = .4225	y = .4065	

This, it seemed, should be the crucial test and should determine accurately which color was the more attractive to insects. The results of the tests made at Wooster are given in Table 6.

TABLE 6. NUMBER OF INSECTS TRAPPED AT WOOSTER, OHIO

	75-w white lamp				75-w yellow lamp			
	Station				Station			
Date	A	B	C	M	A	B	C	M
7/22	17	84	90	64	23	25	20	23
7/23	43	130	369	181	46	32	160	79
7/24	762	1839	6445	3015	288	441	888	539
7/25	953	2021	2671	1882	176	443	767	462
7/26	908	2079	6388	3125	1016	567	881	821
7/29	937	997	1739	1224	171	370	430	324
7/30	237	217	743	399	121	218	68	136
7/31	154	121	—	138	35	124	—	80
8/1	—	1562	—	1562	—	1554	—	1554
8/2	202	494	—	348	229	201	—	215
M per day	347	954	2635		234	398	459	

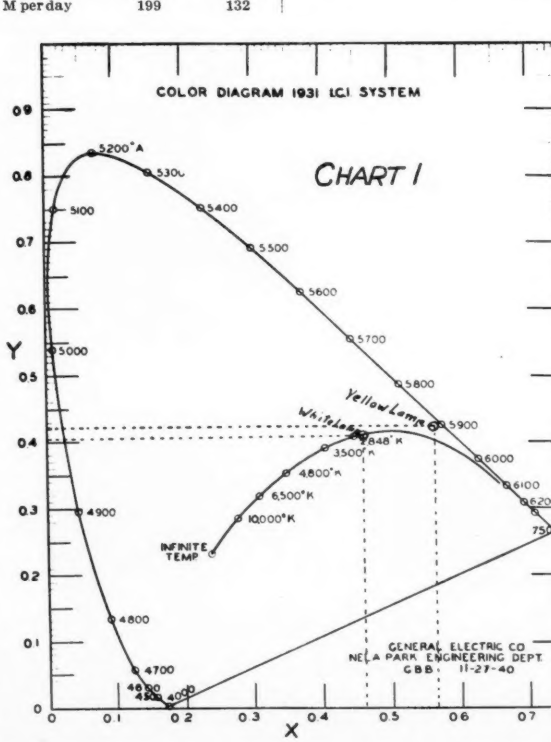
Similar tests were conducted at Nela Park and at Mentor Harbor. The results obtained at these places are given in Tables 7 and 8 and Fig. 12. A total of 36,758 insects was caught by the white lamp against 12,483 for the yellow. This shows that the yellow lamps attracted approximately 34 per cent as many insects as did the white lamps. Similar results were obtained by a well-known testing

TABLE 7. NUMBER OF INSECTS TRAPPED AT NELA PARK, CLEVELAND, OHIO

Date	75-w white lamp	75-w yellow lamp
7/28-29	416	168
8/1-2-3	558	480
8/4-5-6	477	249
8/7-8-9-10	931	683
M per day	199	132

TABLE 8. NUMBER OF INSECTS TRAPPED AT MENTOR HARBOR, OHIO

Date	75-w white lamp	75-w yellow lamp
8/1-3	502	492
8/7-8-9	1672	1117
M per day	362	268



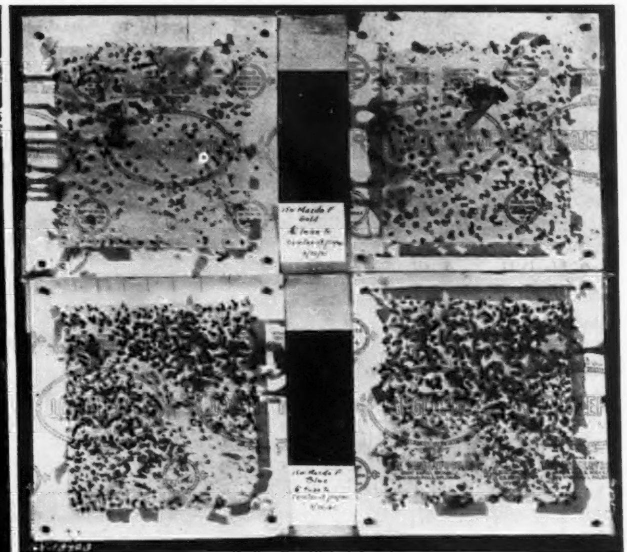
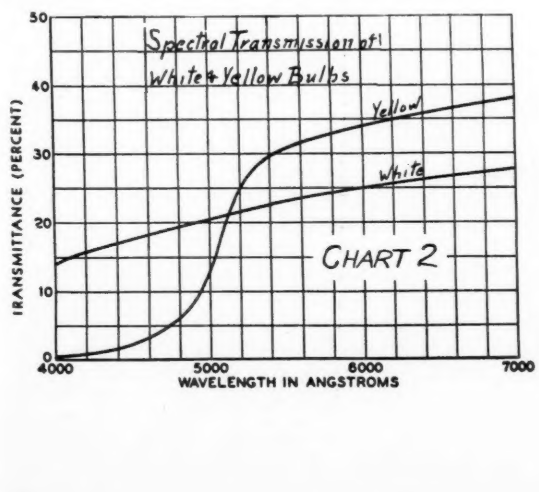


Fig. 14 (Left) Setup for the fluorescent lamp test at 1081 Allston Road, Cleveland Heights, Ohio • Fig. 15 (Above) Relative catches under 15-w gold and blue fluorescent lamps

laboratory in the East using the same lights in a different type of trap and somewhat different testing procedure. We attach considerable significance to this fact.

15-w White vs. 75-w Yellow. The tests cited above indicate that white light was more attractive to insects than yellow light, even at the same wattage, brightness, and candlepower. An attempt was made to determine whether a low wattage white lamp would attract insects to the same degree that they were attracted to a 75-w yellow lamp. A 15-w white lamp plus a 60-w black lamp were used in one trap, and a 75-w yellow lamp was used in the companion trap of each pair at Wooster. (The black lamps used in these tests were regular lamps coated with an opaque lacquer, their purpose being to equalize the heat in the two traps without increasing the light in the traps in which they were used.) The black 60-w lamp was used with the 15-w lamp to generate an amount of heat equal to that of the 75-w yellow, i.e., heat sufficiently high to kill the insects which entered the trap. In this test, then, the wattage and generated heat were equal, but the trap globe brightness of the white light was about one-fourth that of the yellow, though the bulb brightness of the 15-w lamp bulb as seen through the three small openings in the globe, was higher



than that of the yellow bulb. In spite of this big difference in globe brightness, more insects were taken with the white color than with the yellow. The results are given in Table 9 and shown by Fig. 13.

TABLE 9. NUMBER OF INSECTS TRAPPED AT WOOSTER, OHIO

	15-w white + 60-w black				75-w yellow lamp			
	Station				Station			
Date	A	B	C	M	A	B	C	M
8/15	27		82	55	42		40	41
8/16	186	5	298	163	64	1	129	65
8/17-18	88		38	63	25		6	16
8/19	34	36	33	34	17	27	40	28
M per day	67	22	90		30	14	43	

Fluorescent Blue vs. Fluorescent Gold. Another variation in color comparisons was made wherein fluorescent lamps were used. In this instance, the colors tested were blue and gold. According to Weiss et al[1], the gold fluorescent lamp was the one which would be the least attractive to insects and still have a color quality suitable for domestic and industrial use. The insect densities were measured about the gold and blue fluorescent lamps by suspending strips of Tanglefoot flypaper about 2½ ft below each. Sixteen insects were trapped under the gold as compared with twenty-seven below the blue (Fig. 14). Additional tests on those lamps were made at 16259 Oakhill Road, and the catches are shown in Table 10 and Fig. 15.

TABLE 10. INSECTS ATTRACTED TO GOLD FLUORESCENT AND BLUE FLUORESCENT LAMPS AT 16259 OAKHILL ROAD, CLEVELAND HEIGHTS, OHIO

Conditions of test	Date	Gold fluorescent	Blue flourescent	Ratio
Tanglefoot strips vertical 1 ft below 15-w tubes	8/29	884	1817	1 : 2.06
Tanglefoot strips horizontal 1 ft below 15-w tubes	8/29	436	810	1 : 1.86
Tanglefoot strips vertical at 50 ft-c	8/30	556	1034	1 : 1.87
Tanglefoot strips vertical at 5 ft-c	8/31	271	651	1 : 2.40

15-w White vs. 40-w White vs. 75-w White. It has been shown that where much lower wattage white lamps were used in comparison with yellow lamps, the white

lights attracted more insects. To obtain more data on the effect of brightness and intensity of white light on insects, setups were made at Nela Park and at Wooster, in which 15-w white lamps plus 60-w black lamps and 40-w white lamps plus 40-w black lamps were compared with 75-w white lamps. Because these tests were not run concurrently, it was necessary to calculate the results on the basis of percentage of catch in the traps containing the 75-w lamp. The results are given in Table 11 and Figs. 16 and 17.

TABLE 11. TRAP-CATCH OF WHITE BULBS OF DIFFERENT WATTAGE WITH HEAT WITHIN TRAPS PRACTICALLY STANDARDIZED BY SUPPLEMENTARY BLACK BULBS

	Percentage of Catch Per Day in 75-w Trap		
Location	75-w	40-w	15-w
Wooster — Station A	100	105.6	113.3
Wooster — Station B	100	76.3	87.2
Wooster — Station C	100	118.5	88.4
Nela Park	100	93.6	80.8

In another test, white light from a 15-w lamp in one trap was compared with a similar lamp used with an auxiliary 60-w black lamp in another. In this test the brightness and candlepower were identical, but there was a big difference in the wattage, and, consequently, in the heat generated in each of the traps. The results are given in Table 12 and Fig. 18.

TABLE 12. INSECTS TRAPPED AT 16259 OAKHILL ROAD, CLEVELAND HEIGHTS, OHIO

Date	15-w white lamp	15-w white + 60-w black lamp
7/28 — 8/1	619	8,686
8/9-10	441	1,750
M per day	177	1,723

No attempt was made to account for the big differences obtained, but it is probable that the temperature within the globe containing the 15-w lamp alone was insufficient to cause rapid death to the insects which entered.

Methods of Light Application. Data previously presented in this paper indicate that colored lights would not eliminate night-flying insects from a given area. Therefore, tests were made of different methods of applying light in order to study the effect upon the insect population.

Reflected Light vs. Bare Lamps. When a bare lamp is suspended in the open, it is visible from every direction, and therefore to a greater part of the insect population than would be the case if the lamp was partially concealed within a reflector. That this is true is shown by data obtained in a one-night test at 16259 Oakhill Road, Cleveland Heights, on the night of August 26. Two 40-w white lamps were used, one being exposed on all sides and the other contained in a reflector. The measure of difference was the number of insects caught on a strip of Tanglefoot flypaper suspended vertically eighteen inches below each lamp. The catch was 16 insects under reflected light and 78 insects under the bare lamp.

Another test which demonstrated the effect of reflectors on the catch of insects was made on August 24. On this occasion a bare 100-w yellow lamp was compared with a 25-w yellow lamp in a deep-bowl aluminum reflector. Each lamp delivered 5 ft-c (foot-candles) on a strip of Tanglefoot flypaper suspended below the lamps. The numbers of insects trapped were 1181 insects under the bare 100-w yellow lamp and 125 insects under the 25-w yellow lamp in reflector. Fig. 19 shows the relative density of the insects captured during this test.

Attracting Insects Away from a Given Area. A rather interesting experiment on the relative drawing power of different light sources was run at 16259 Oakhill Road. One evening in August when the little midges came through the porch screen in such numbers that it was uncomfortable to sit on the porch with two 100-w pin-it-up lamps burning, a 275-w mercury arc (RS sunlamp), a source that is exceedingly attractive to insects, was mounted 6 ft outside of the screen. In a very few minutes practically all of the midges had gone out through the screen and were around the RS lamp. This lamp was then turned off, and the insects were soon back inside the screen. This test was repeated several times with the same result.

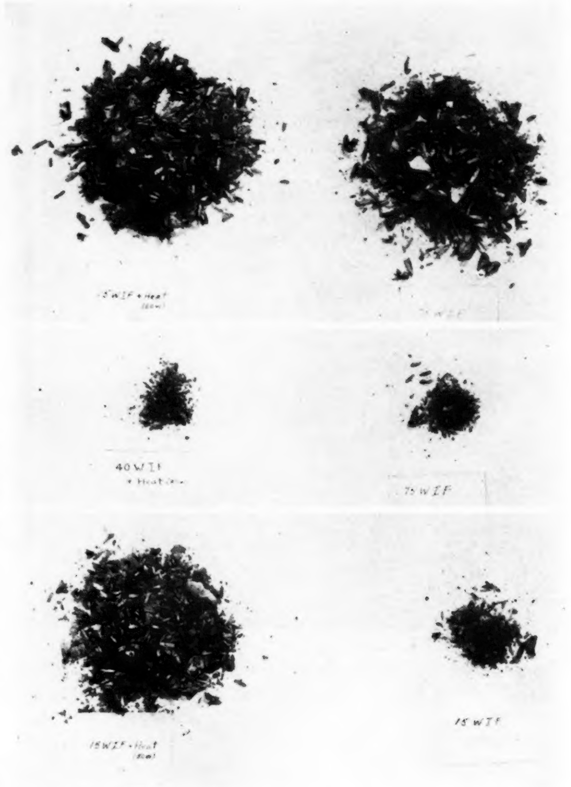


Fig. 16 (Top) Relative catches of 15-w inside-frosted lamp plus 60 w of heat from a black bulb emitting no light (left) and 75-w inside frosted bulb (right) • Fig. 17 (Center) Comparative catches of 40-w inside-frosted lamp plus 40 w of heat from a black bulb (left) and 75-w inside-frosted lamp (right) • Fig. 18 (Bottom) Comparative catches of a 15-w inside-frosted lamp (right) and a similar lamp plus 60 w of black heat (left)

Projected White Light vs. Local Yellow Light. Studies of the effect upon insects of a projected white light as compared with a local yellow light were made by mounting a 150-w white projector spot lamp at a height of 20 ft above ground at 1081 Allston Road (Fig. 20) and at Wooster. At Wooster the light was projected upon a white-topped table on the ground, 36 ft from the light. Nearby, but completely hidden by bushes from this setup, two 75-w bare yellow lamps were suspended above a similar white-topped table. These lamps could be raised or lowered as necessary to adjust the light on the table top to 6 ft-c, which was the level of illumination on the table under the projected light. In this experiment the traps used consisted of 8x8-in squares of Tanglefoot flypaper pinned to wooden frames and laid flat on the table top. Two such frames were used on each table. The results are given in Table 13.

TABLE 13. INSECTS CAUGHT ON TANGLEFOOT TRAPS UNDER PROJECTED WHITE LIGHT VS. LOCAL YELLOW LIGHT OF SAME FOOT-CANDLES (6) AT TABLE TOP

	INSECTS TRAPPED					
	White light projected 36 ft			Yellow light approximately 4 ft above trap		
Date	Trap No. 1	Trap No. 2	Total	Trap No. 1	Trap No. 2	Total
8/16	3	5	8	101	151	262
8/19	6	5	11	71	83	154
8/20	0	5	5	20	25	45
8/21	2	1	3	19	18	37
8/23	1	2	3	109	104	213
M per day	2.4	3.6	6.0	64.0	76.2	142.2

The test which produced the data given in Table 14 differed from the previous test only in that Trap No. 2 under each light was suspended vertically about 2 ft above the table top and consisted of two sheets of 8x8-in Tanglefoot flypaper squares pinned back to back on the frame, thus doubling the size of the catching surface. Under the yellow light, the foot-candles at the traps were 11 and 6, whereas under the projected light there registered 6 ft-c at both traps.

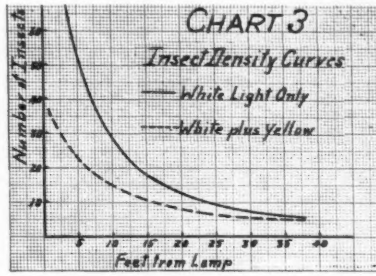
TABLE 14. INSECTS CAUGHT ON TANGLEFOOT TRAPS UNDER PROJECTED WHITE LIGHT VS. LOCAL YELLOW LIGHT*

	INSECTS TRAPPED			
	White light projected 36 ft		Yellow light	
Date	Trap No. 1 6 ft-c	Trap No. 2 6 ft-c	Trap No. 1 6 ft-c	Trap No. 2 11 ft-c
8/13	—	2	—	19
8/14	2	3	8	10
8/15	4	9	95	121
8/25	6	7	244	309
8/26	7	10	258	411
8/27	7	7	63	50
M per day	5	6	134	153

*In Trap No. 1 in each instance, the Tanglefoot was flat on the table top, whereas with Trap No. 2 the Tanglefoot was suspended vertically about 2 ft above the table, which was approximately one-half the distance from the yellow lamp to the table top. This accounts for the 11 ft-c at Trap No. 2, and 6 ft-c at Trap No. 1.

Distribution of Insects Along Beam of Projected Light. Projected white light results in a lower concentration of insects at a given place somewhat remote from the projector than under local yellow light of the same intensity.

In order to determine the reaction of insects subjected to projected light, a series of Tanglefoot traps were strung in the beam of the projected light to the table top previously described. These traps are shown in Fig. 21. These traps were operated for a total of six nights, producing the data given in Table 15 and Chart 3.



On an evening when insects were thick, several of us tried reading out-of-doors under the RS lamp at a distance of approximately 6 ft, where the level of illumination was 20 ft-c. The insects made us very uncomfortable. The RS lamp was then turned off and 20 ft-c of light was projected onto the reading matter from a distance of about 15 ft. Under this condition, there was only an occasional insect buzzing around.

Distribution of Insects When White Light Is Projected into an Area Illuminated by Bare Bulb Yellow Lamps. The influence of a beam of white light when projected into an area illuminated with yellow light was studied by adding to the setup discussed in the previous section a yellow lamp suspended over the table upon which the beam from the projector lamp was focused. This yellow light was adjusted to deliver 6 ft-c at the table top in order to produce the same level of illumination as produced by the white light at that point. The data obtained are given in Table 16.

DISCUSSION

The work done in 1940 was somewhat exploratory in nature, but several important findings resulted. It showed that no color among those used was actually repellent to insects, although the attractiveness varied considerably as noted in the differences between the numbers and weights of the insects caught in the differently colored traps. The insects attracted to all the colors were well distributed among the different orders of the nocturnal forms. This

TABLE 15. INSECTS CAUGHT ON TANGLEFOOT TRAPS UNDER PROJECTED WHITE LIGHT AT WOOSTER, OHIO

		Insects caught						
Distance from light	Foot-candles	8/13	8/14	8/15	8/25	8/26	8/27	M
36′	6	—	2	4	6	7	7	5
36′	2	2	3	9	7	10	7	6
30′ 10″	9	1	3	6	9	11	7	6
26′ 6″	12	3	7	9	15	16	20	12
21′ 5″	24	0	6	11	35	20	24	16
16′ 3″	32	1	10	10	32	22	15	15
10′ 8″	45	4	2	26	53	43	21	25
4′ 8″	75	3	4	74	86	108	71	58

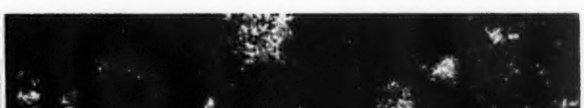


Fig. 19 (Left) Relative catches under 5 ft-c of reflected yellow light (top) and 5 ft-c from bare bulb yellow lamp (bottom) • Fig. 20 (Right) The setup for the projected yellow light and bare bulb light test at 1081 Allston Road, Cleveland Heights, Ohio

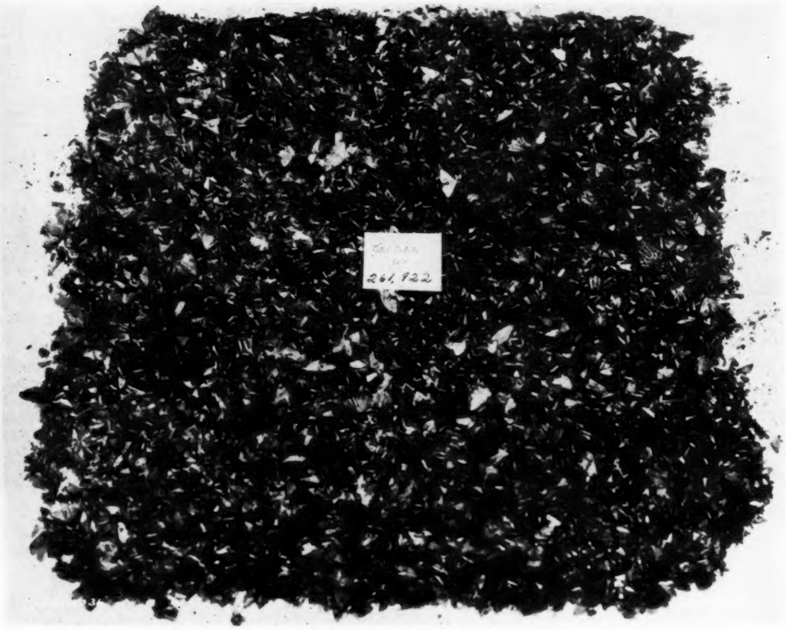


Fig. 21 (Above) String of Tanglefoot flypaper from projector spot lamp to table at Wooster, Ohio • Fig. 22 (Right) Total insects (261,922) trapped in 1941 tests, exclusive of those caught on Tanglefoot flypaper

TABLE 16. INSECTS CAUGHT ON TANGLEFOOT TRAPS UNDER PROJECTED WHITE AND LOCAL YELLOW LIGHT OF EQUAL FOOT-CANDLES ON TABLE TOP, WOOSTER, OHIO

Distance from spotlight	Distance from yellow light	Insects caught 8/28	8/29	8/30	M
36′	2′*	7	10	34	17
36′	4′**	3	4	9	5
30′ 10″	6′	6	5	11	7
26′ 6″	11′ 4″	4	1	13	6
21′ 5″	16′ 5″	5	2	27	11
16′ 3″	21′ 7″	6	3	19	9
10′ 8″	27′ 2″	5	11	34	17
4′ 8″	31′ 10″	8	6	85	33

*Suspended above table the white lamp delivered 6 ft-c and the yellow lamp 9 ft-c.

**On table top each lamp delivered 6 ft-c.

fact made it unnecessary to identify the insects collected in future tests. Thus a tremendous amount of difficult work was saved this year.

There was found to be no relation between the weight and the number of insects captured. The insect nuisance is more closely tied up with the number of insects in a given area than with the weight, because one large-sized moth or beetle may weigh more than several thousand irritating gnats or midges. Weighing as a means of determining the population of insects or the degree of attractiveness of any color or arrangement of lights was abandoned in favor of counting or otherwise calculating the number of insects in the trap.

Yellow light, when compared with white light of the same candlepower and brightness, proved to be approximately 66 per cent less attractive to insects. It was shown that even though a 15-w white lamp was used vs. a 75-w yellow, the white lamp still caught more insects.

The color produced by the gold fluorescent light was much less attractive to insects than blue fluorescent light.

It would be expected that within certain limits a brighter light would attract more insects than a less bright one of the same color. This was true in general, particularly if we consider the relative brightness of the surrounding area and the light source. The higher wattage inside frosted lamps, while somewhat brighter than the lower wattage inside frosted lamps, have not materially increased the differential between the light source and its surroundings. This is substantiated by the data shown in Table 11.

Color and brightness of light appear to have little value in completely ridding an area of the nuisance of night-flying insects, and so attention was given to the placement of lamps and the distribution of light on an area and their effects on the insect population. The use of reflectors, which more or less concealed the lamp and directed the light in one general direction, was studied. Invariably the lamps which were bare attracted many times the number of insects than were attracted by lamps within a reflector. Undoubtedly this result is due to the fact that the light from a bare lamp is visible from all directions, and therefore to a larger insect population than that from a lamp within a reflector, especially when the light is directed toward the ground from a low altitude.

The result with reflectors suggested the use of projected white light in comparison with local yellow light. At once the large majority of the insects were found to be absent at the point of interest, whereas under the yellow light many remained. Further measurements showed that the insects were drawn away from the point of interest toward the somewhat remote spotlight, where the population was dense. Superimposing a bare yellow light above, but near the point of interest, changed this distribution but little and only in the immediate vicinity of the yellow lamp.

As a matter of general interest, all of the insects caught in the 1941 tests, with the exception of those caught on Tanglefoot, are shown in Fig. 22, a total of 261,922.

CONCLUSIONS

1 Lights of all colors tested were found to attract insects to a greater or lesser degree, and none was found to repel insects.

2 The colors on which comparable data are available arrange themselves in order of least to most attractiveness to insects as red, yellow, white, and blue.

3 Bare lamps attract many more insects than do lamps contained within deep-bowl type reflectors or reflector and projector type bulbs.

4 By the utilization of lights of the proper kind and the correct distribution of light, few insects were attracted to the test area and some may have been drawn away from it.

"Agricultural and Industrial Research Parallels"

EDITOR'S NOTE: Following are most of the prepared discussions of the above titled paper by Dr. Anson Hayes which was presented at the fall meeting of the American Society of Agricultural Engineers at Chicago, December 1941, and published in the preceding issue of AGRICULTURAL ENGINEERING:

Discussion by Geo. W. Kable

President, American Society of Agricultural Engineers; editor, "Electricity on the Farm"

IF YOU do something worth while in research, it is only worth while if it is made known to those of your fellow beings who can make use of it. In his paper Dr. Hayes said, "The scientist merely seeks the truth. The application of that truth is in the hands of the masses." *The masses must know* in order to apply.

As agricultural engineers, the type of research in which we are most interested is that which makes this world a better place in which to live, that is for the farmer and for the public whom he serves. The measure of the success of our research is, Will it help someone? To help someone, he must know about it; know about it in terms he can understand — for example, movies for car wheels, newspaper items for sulfanilamide, standards for plow simplification, magazine articles for gas nutcrackers. The research man must first tell his own story — sell his discovery. He must sell it to the extension man, the advertising or sales manager, or the public; sell it, not for self but for service to others.

I wonder how many appropriations have been made for research work done by the man in the next office whose results are still "under a bushel". On the other hand, there are some men who are known for their research, who have done relatively little research. They told what they did when they did it; and it may have saved someone from useless duplication.

The man who puts himself on record intelligently for what he is doing *now*, for progress results, for final proofs, is the one who renders the greater service. If you are an industrial research worker, you will tell it to your company; if agricultural, to the farmers. But *you will tell it for the good it will do others.* And profit will come equally from the usefulness of the discovery and the expertness of the telling.

Discussion by Dr. M. L. Nichols

Assistant chief (in charge of research), Soil Conservation Service, U. S. Department of Agriculture

I WAS particularly interested in Dr. Hayes' remarks about the shift from the conception of "research for science's sake" to the modern conception of research as the means of attaining immediate objectives quickly in an organized manner. He speaks of this shift as though this conception was something in the past. To men like Dr. Hayes this is of course the case, but let us look at things as they actually exist today in agriculture, a field of industry in which we are occupied.

I am perfectly willing to take, as an example, the field of soil conservation in which I am employed. I have made no careful investigation, but I think it conservative to say that 25 per cent of the men working in actual operations in my own organization (S.C.S.), honestly believe that "research in conservation" is something which should be done and will finally pay, but is really of little immediate moment. This in spite of the fact that most of the practices they are using on farms are in their present forms largely developments of research.

From my observation of extension workers I would say an equal percentage have about the same opinion of agricultural research in general. The confusion is largely in the meaning of the word "research" itself. In fact, many extension and action workers themselves are actually engaged in disorganized forms of research, but call it something else, because of legal difficulties or, more generally, ignorance. Some excellent practical research has been done by farmers, but they never think of it as such. Just as there are many Christians who have never joined a church, there are many research workers who have never written up a project. There is no possible progress except by research or its equivalent, call it what you may. The only question is, Shall we proceed in a planned, orderly, and systematic manner, or shall we improvise as we go?

The conception of research as a service for continuous development, one that is immediately useful, is not very generally accepted in agriculture. I believe that practically all research directors have long accepted this conception, and that the bulk of modern research is live and active, but we are still judged on the old basis. In the present emergency this viewpoint among many men, even in high positions, is causing all of us grave concern.

The point made by Dr. Hayes of considering the sales angle when developing a product is one that is exceedingly important to agricultural engineers. Usually we are working on a process rather than a product, but to be effective it must be "sold" to the user. One trouble with much of our research is that it is not directly connected with our "sales" organization. Some research is actually concerned with sales, in the literal sense, of agricultural commodities. All of us who are responsible for administration have the "patent" question come up again and again. The sales angle is always there. We have the oft-repeated request to change over a machine now in large-scale production so that it will meet some local need. The many things involved in such changes are rarely considered, usually not even understood by those requesting the changes. We have not considered the sales or application angle, and much time and work is lost. Sometimes we actually do our cooperating manufacturers a disservice by recommending any changes in design without enough facts.

Too frequently there is a missing link between the research worker, the manufacturer, and the farmer. There is often a gap of many years between the discovery of a new fact or process and its general application. Something new is developed and published, and it is vaguely assumed that someone will develop the application. The research worker himself does not have the facilities for field trial or pilot plant tests needed to carry the work to the point where it is readily salable. Frequently machines are involved; the process must be implemented. This is an essential part of the research from a practical viewpoint.

We have in the federal action programs and in the agricultural extension service a sales agency, but much of our product is not developed into a marketable condition. We need very much indeed to consider the sales angle in our work. The agricultural engineer is in the key position for the "application research" necessary.

Discussion by Dr. W. E. Kuhn

Manager, technical and research division, The Texas Co.

I WOULD take exception to two points made by Dr. Hayes, namely, that "an industrial research man should be familiar with the production department of his company", and that "knowledge of sales problems and procedures are also important."

True, a part of any scientific organization must be fully cognizant of the sales requirements and their problems, and also of the current manufacturing possibilities and limitations, but there should be a group — and not too small a group — that is not influenced by the ideas and practices of its predecessors, a group that will investigate new and untried routes rather than widen and improve the main road. In this day of rapid advances, some old and well-trodden main roads have been superseded by better routes because of a curious explorer.

I would like to refer to a statement made by the late Harry L. Horning, formerly president of the Waukesha Motor Company, which impressed me as being very fitting, with only slight modifications, to business in general, and directly applicable and definitely worth keeping in view by research supervisors. He said we should try to avoid the following faults most common in most research laboratories:

1 A general hesitation in getting under way

2 The tendency to go off on a tangent or become interested in a by-product of the research

3 The tendency to delay the finish which results in loss of the greater value of research

4 Psychological collapse when the investigation is done with great delay in following through to the application of an idea

5 Skepticism of the practical man toward the results of the research undertaking

6 The difficulty of getting the market and the world in general to adopt the results of research.

Discussion by Dr. J. B. Davidson

Head, agricultural engineering department, Iowa State College

DR. HAYES has presented in a most interesting and effective way the benefits that may come from wisely directed and efficiently conducted research. He has clearly pointed out that in any scientific or industrial field of endeavor there is no greater source of strength to cope with the problems of the present, or a more valuable reserve of competency to deal with the new situa-

tions of the future, than knowledge properly classified and available for application. The frontiers of knowledge are so broad that there is no possibility of overemphasis, although there may be duplication of effort through lack of coordination.

It may be worth while to consider the coordination of research by public institutions and private or industrial organizations. On occasion fear has been expressed that the efforts of these two groups of research agencies may find their efforts in conflict. It is believed that such a situation cannot only be avoided, but the researches conducted by the groups with different sources of support may be made to supplement each other. It is the purpose of this short discussion to examine briefly into the objective and types of researches to which each group should combine its activities.

Research by manufacturing concerns, for example, must be closely related in purpose and scope to the products which the concerns are producing or may produce. It is not necessary, however, that such researches be necessarily restricted or limited in such a way as to bar the possibility of adding to the general stock of scientific knowledge.

The researches of public-supported agencies, on the other hand, may well be directed toward the securing of more general knowledge which may be valuable directly to the public or to public groups, such as the industries as a whole.

It would appear that there are at least three types of research which may occupy the attention of public research institutions such as the federal laboratories and state experiment stations.

1 Research in rather broad or general fields of interest to establish the relationships of the various influences and factors involved in processes or techniques should be given special attention by public institutions. New information in such fields being of wide application, does not conflict with the best interests of the individual concern or manufacturer. A few examples in the agricultural engineering field may illustrate this type of research. The study of the storage of shelled corn is an example. It is recognized that field shelling of corn is dependent upon a successful technique and adequate facilities for the storage of corn of high moisture content. This is a subject of interest to all manufacturers concerned with the manufacture of field shellers and also to all farmers who may be interested in the storage of shelled corn. A study of the characteristics of pneumatic tires for farm machine wheels is likewise of general interest to large groups. A research project by our Society in this subject was supported by seventeen manufacturers a few years ago.

2 Another type of research in which public agencies working in the field of agricultural engineering may well engage is that of making engineering analyses of general farm operations or techniques such as the growing, curing, or processing of a crop. Since engineering deals essentially with labor efficiency, power economy, and the use of equipment expended in production of a crop, this is a starting point for a program of improvement. With definite information as to the amount of labor used in each phase of the enterprise, effort for improvement can be intelligently directed.

3 Public agencies may properly conduct exploratory researches into fields involving broad changes in conventional procedure. Many examples may be cited. Researches into the growing of crops with the residue from the previous crop left on the surface, or "mulch culture" as it may be called, is a good example.

Another example of such an exploratory study would be the economic and engineering possibilities of the power take-off-driven trailer upon which various farm machines may be mounted in connection with a light-weight tractor. There apparently could be no better way to secure widespread consideration of the idea involved than to build and test such an outfit.

Public institutions are not in a position to design finished machines, as such designs are necessarily related to the equipment to be used in production. New ideas of new devices and machines will come to public research workers, but such results should be looked upon as a by-product rather than an objective of such researches.

Discussion by Theo. Brown

Chief, implement research development, Deere & Co.

I SHOULD like to emphasize the value of enthusiasm to a person engaged in creative and research work. Not only should one have interest in his work, but he should have enthusiasm as well. He should have his work uppermost in his mind. Work of this type is not measured by the clock, for unconsciously ideas, plans, and methods of procedure come into being at any hour of the day or night. Some of the best ideas are born at unusual hours.

Then, too, it is necessary to have an open and unbiased mind. When one line of endeavor comes to a dead end and results are negative, don't spend time trying to prove wrong is right. Wipe the slate clean and make a new start with a fresh mind. A tired mind does not create.

Creative work needs encouragement, so for those in charge it is well to remember that a little praise is a good lubricant to better work.

Discussion by Dr. R. W. Trullinger

Assistant chief, Office of Experiment Stations,
U. S. Department of Agriculture

I RECOGNIZE in Dr. Hayes' paper the usual direct statement of a competent and experienced director of research. He makes it plain that the objective and procedure of true research, which is serving an industry, varies only with the subject matter concerned. He shows that agriculture is an industry which must be served by research the same as any other industry and emphasizes that agricultural research has been at it a little longer than the others perhaps.

I think he stresses the "college professor" aspect of so-called university research a little too much perhaps, which may add to the popular misconception that all publicly supported research and all research in endowed or subsidized institutions is of the type popularly attributed to college professors. As a matter of fact, the agricultural experiment stations employ many college professors who bring a high and effective type of scientific thinking and procedure into the solution of economically important practical field problems. However, this does little harm and what follows certainly clarifies the situation.

He very properly lays emphasis on the fact that "agricultural research administration is concentrated in the office of the director, rather than in the subject matter department", which he characterizes as an effective method for industrial research as well. He also emphasizes the importance of "deliberate planning of research projects resulting in systematic, orderly and complete scientific attack", which he says are "all familiar components of agricultural research now found in industrial research organizations". By implication he points out that group action by all scientists concerned in a problem is essential to its permanent and most useful solution. I believe that this point might be stressed a little more.

Dr. Hayes' account of accidents in scientific research is most interesting. I sense in his statements that some of the most useful fundamental principles of science which have appeared to be accidental discoveries, were not accidents at all but were the results of well-planned, orderly, and calculated searches for certain fundamental answers which were essential to further progress. In other words, depending of course on how one looks at it, accidental discoveries of great importance are rare and in most instances simply do not "just happen".

Discussion by John A. Slipher

Professor of agronomy (extension), Ohio State University

THE notion that the agricultural experiment station's place in technology is to solve problems that farmers place before it, is a challenge to a true concept of what constitutes research. In the first place, it presumes that problems in agriculture are identical with surface manifestations of trouble, and, secondly, it implies that the farmer is able to identify his problem. The latter is a glorious supposition.

Some problems, and often the most worth-while ones, may defy ready identification. Actually, it may require research to discover what "research" should attack. Are we sure that tracking down and exploring the true roots of the problem are not just as much an organic part of research as the solution itself? The body of the problem may not be on the surface, but it may lie under the surface, obscure, hidden; *and* much exploration may need be undertaken to stake it out and to identify it.

Another aspect of the problem-hunt is that inference may sometimes trick us. Transparent inferences may be infected with falsity. Then, too, familiarity and tradition may blind us. A glaring example of this type of deception may be cited in the water problem on the flat, heavy land of northwestern Ohio. That area was drained, when first put to the plow years ago, with tile lines placed systematically four rods apart.

Now, after 60 years of plowland farming, farmers declare (and their observation is correct) that the land no longer drains as quickly nor as satisfactorily as originally. They say we must put in (and many of them do) additional tile lines between the existing lines. Has not the farmer in this instance inferred that the original solution of the drainage problem, namely, tile drainage, is still the solution on this land? Should the director of the

experiment station, upon request of the farmers of the area, therefore proceed to work out the spacing and depth and other techniques of tile installation that will rid these lands of excess water?

From another field of agricultural technology it is now being demonstrated that the disappearance of the original high content of organic matter in this soil has cramped its facility to move water through its body, *and* that that situation is the key to its "logginess" toward water. In consequence, the soil, as a vehicle for moving water vertically and horizontally through itself, has lost capacity. Accelerating flow of water within the soil may be an organic arm of the problem and perhaps quite as much so as the tile itself. So the problem can belie its cloak.

Citation of this situation and the mistaken identity of the problem in it is ample proof of the danger that lurks in accepting supposed problems which, as in this instance, may be burdened with tradition. When the experiment station presumes to advertise to the public that it disclaims the realm of identification of problems and concerns itself with investigating only those the farmer brings in, we are likely to find ourselves down some blind alleys. Again, is not the province of research to seek out and to track down true problems?

Apropos the qualifications of the young man who engages in research work, Dr. Hayes states "A student must be plastic in his thinking." I should like to ask this question: How is he to develop that quality unless his teachers are also plastic in their thinking? Although Dr. Hayes addressed his remarks to the educators in this audience, he did not say whether he expected the educators to consciously and objectively direct teaching so as to enhance plasticity of thinking. The mind, if it does become more plastic, will change because of the influences of the type of teaching and not because of the amount of factual knowledge crowded into it. Knowledge and thinking are not synonymous. A mind may be rich in knowledge but feeble in power to think. Knowledge is merely a "way station" on the road to understanding. Whether one reaches his destination in thinking — that is, a logical and safe conclusion — will depend upon the method of thinking.

To be facile, the mind needs to be equally skilled in inductive and deductive procedures. So much of agricultural technology has been based upon and has been taught from the standpoint of factual material and that has confined the mental processes of the college student to deductive thinking to the almost total exclusion of reflective processes. This is a sad commentary upon modern educative methods, particularly in view of the fact that some of the greatest achievements of the human mind have been accomplished by inductive thinking. Perhaps we need to consider (1) whether the dual-thinking type of mind does better adapt itself to research requirements and (2) if it does, can education in technology so orient its teaching techniques as to strengthen dual capacity? Objectivity in research, so keenly stressed by Dr. Hayes, presupposes a generous application of reflective thinking. It assures breadth of attack as well.

Discussion by C. J. Hurd

Chief, agricultural engineering development division, Tennessee Valley Authority

DR. HAYES raises the question of the balance between industrial and institutional research. It is on this problem that I wish to present the thinking of the Tennessee Valley Authority in regard to its farm machinery research program conducted as one phase of the regional agricultural development work in that area. As with other agricultural activities, the research is conducted in full cooperation with state and local agencies and cooperating farmers. The majority of the research projects are with the land-grant institutions, thus contributing to the "grass roots" procedure in implementing their agricultural program. The farm machinery projects selected are those which, in the opinion of the agricultural authorities and farmers in the region, are most important in the rebuilding of impoverished soil and at the same time in contributing to increased farm income.

Research work on new or improved farm implements is vitally important, as it may well be the missing link between a "paper program" and the actual widespread and extensive agricultural improvement work by farmers so necessary to our national economy.

I subscribe to Dr. Hayes' impression that there is no conflict between industrial and academic research, yet I wonder if we are putting the push behind our research so that equipment developments are manufactured and put out aggressively through recognized distribution outlets, in order that large numbers of farmers can see these new items and purchase them if they meet their requirements. This is a challenge to every research worker or administrator of a research program.

Public research groups should not be afraid of becoming "commercially minded" in presenting through a systematic and orderly procedure the results of their research investigations to suitable and interested manufacturing organizations. The exact arrangements, of course, will depend upon the nature of the development and the policy of the particular public service group.

I want to briefly tell of one farm implement development to illustrate how the Tennessee Valley Authority and the cooperating Valley land-grant institutions treat such problems.

Farmers and agricultural experts in the region requested the development of a simple, inexpensive implement for seeding fall and spring grain along with phosphatic fertilizer on sloping hill land having a legume crop, in order to obtain maximum year-round soil protection. Such an implement required careful investigation to meet these requirements, and yet be practical when used on the farm. In the development novel features were discovered, not appearing in other seeding implements, upon which a patent was granted.

Research men in the Authority and land-grant institutions were not satisfied with stopping there. They recommended that a number of demonstration machines be built and distributed by the agricultural extension services to get test data and also to secure the valuable reaction of farmers. Fifty machines were therefore constructed, and the first year over 1500 acres were seeded by farmers throughout the Valley.

Following favorable reaction, at this point a systematic program of acquainting manufacturers in the area with this development was undertaken, and subsequently one company entered into a non-exclusive license agreement to put the machine on the market.

This still did not complete the cycle. The cooperating land-grant institutions issued a circular on the subject, the manufacturers put out an attractive mailing piece, and every fall the extension service conducts demonstrations in areas where the equipment is applicable. Sales to date total about 400 units with the field program in its third year, with every indication that sales will increase year by year.

Still the cycle is not complete. Improvements in the machine have been studied by our engineers, which will be passed on to the manufacturer. That will make the machine still more effective.

Similarly, a small thresher for hill farms, electric units for sweet potato curing, and an improved hay drying system have been developed and are now in sales channels.

This course of action from the research laboratory of the public institution through the test-demonstration stage, then to the manufacturer, is not new, yet I wonder how many fine developments of public institutions become lost in a tangle of red tape or by the desire of the research men to reach perfection in the device before they could get up courage to approach a manufacturer. Let us follow Dr. Hayes' gentle reminder: "There is no conflict between the industrial research laboratory and the academic laboratory."

Discussion by R. M. Merrill

Agricultural engineer, Bureau of Agricultural Chemistry and Engineering, U. S. Department of Agriculture

DR. HAYES says that "the research worker should be associated constantly with scientific societies and should be in close contact with other groups in his own organization so that facts developed in one group may be available to other groups." The worker who has had years of experience in the commercial aspects of the field in which he is working, needs such contacts in order to keep abreast of conditions, and the research worker who has not had the opportunity to get experience in his field before going into the laboratory, certainly cannot make the most progress without such contacts. To me the statement covers a most important angle of a research worker's job but is an angle which is sometimes difficult of attainment. In many instances the research worker becomes so engrossed in his work that he does not want to take time to make the desirable outside contacts, or perhaps his employer, for some reason, cannot allow him to take the necessary time.

If it is impossible in a research organization to allow individual workers to make contacts with other groups, the work should certainly be directed or guided by someone who does have such opportunities. The supervisor or director should be capable of assisting the worker to recognize what Dr. Hayes calls "accidents" when they occur, and also to recognize findings which may not be pertinent to the immediate problem but may be of tremendous importance to some other problem with which the individual research worker is not familiar. This means that the director or supervisor must follow closely the details of the research being carried on rather than depend on merely examining results as reported by the worker. It is very probable, in many cases at least, that the

worker will only report what he thinks is applicable to his assigned problem and may miss points of considerable importance.

With this type of guidance or supervision the research organization should make the greatest possible progress with the least duplication of work and with the greatest chance of discovering so-called "accidents".

Discussion by John A. Scholten

Research engineer, Forest Products Laboratory, U. S. Department of Agriculture

RESEARCH is a systematic exploration of the unknown. The developments cited by Dr. Hayes, as well as such familiar products as cellophane, plastics, rayon, nylon, sound pictures, are not the results of a hit-or-miss search, but are the fruit of systematic exploration. Ages of trial-and-error, or rule-of-thumb, methods could not have brought about many of these revolutionary developments.

It is difficult adequately to appraise the value of research either in regard to monetary rewards or its effect on society. This lack of an appropriate yardstick for measuring results has often militated against necessary expansion. One need, however, only consider the widespread use of many inventions based on research to realize its value. The fact that industries which have made the most spectacular growth during the last 25 years are also foremost in research, is further evidence that research is remunerative.

Research, however, has broader application than immediate benefits. In the field of forest products, for example, research cannot help but make wood and its derivatives serve the public better. Improvements in the quality and quantity of these products affects the demand for wood which can be grown on the millions of acres of land better suited for growing forests than for other purposes. The use of this land for timber growing means not only industrial development with its attendant contributions to the community, on otherwise worthless territory, but in many cases it also means the conservation of the soil, water, and recreational facilities, the importance of which is more and more being recognized.

In one of Dr. Hayes' illustrations we see the development of hybrid corn reach a successful conclusion. Unfortunately most individual efforts are not so productive. The era of the lone worker who makes a world-shaking discovery is passing. It still happens sometimes but not often. Nowadays it is teamwork in the laboratory that gets results. May we hope that the mass effort, required in research activities at the present time to cope with our war needs, will serve to accentuate the importance of more adequate research and research facilities during more normal times.

Discussion by Dr. F. A. Brooks

Agricultural engineer, California Agricultural Experiment Station

DR. HAYES has discussed industrial research directed specifically toward the improvement of a given product. He has skipped over the first hurdles of fundamental research which concern the defining of the problem, paying but scant attention to the well-tried axiom: To state the problem explicitly is half the answer to it.

In his excellent example of wheel research, Dr. Hayes emphasizes the achievement of a slide rule for calculating internal stress and barely mentions the principal research accomplishment which was the discovery, during preliminary analysis, of the significance of thermal cracks. All subsequent development would have been useless if the preliminary analysis had been unsound.

Of course there might be some accidental discovery during research along a misconceived path which might be made of great value if the objective is changed. However, in organized research it must be kept in mind that there is the vital preliminary step in research procedure—the correct analysis of the problem—before the research project can be properly scheduled.

Research toward a set objective has long been practiced in the regular engineering departments of industries. This was in the deliberations on what changes to make in products in order to remedy defects revealed in service. In fact, the entire automotive industry has been built in this manner. Automobile "performance", as we know it, would be utterly impossible, if the conservative gear-design standards of general industry had been adhered to.

In spite of, or because of, such great accomplishments by the engineering departments in reaching "a successful conclusion by having a set objective", there has been a phenomenal growth of industrial research laboratories separately from engineering departments. Evidently industry wants better research results than were possible from the engineering departments. Hence, there must be a potent reason other than developmental research to explain the trend of industrial research toward fundamental knowledge. It seems likely that this additional incentive lies in the fear of possibly fatal expense of guessing the wrong explanations of troubles.

It is a common finding that fundamental research confirms current practice, but often it shows that right actions have been taken for wrong reasons. Certainly, if the solution of a problem is to be positively sound, one must know correctly what the real problem is. Hence, it is the primary duty of industrial and agricultural research to find the right reasons.

Discussion by C. E. Ramser

Principal soil conservationist, and chief, hydrologic division (research), U. S. Soil Conservation Service

I WAS particularly impressed with the broad view Dr. Hayes takes in his paper as to what constitutes research, since too often discussions on this subject are confined to the more fundamental aspects. In soil conservation, a comparatively new field of work where adequate research is extremely meager, it is important that research projects yield results for immediate application to practical field problems. Such research is sometimes called "applied" research as contrasted with more fundamental research usually referred to as "pure" research. However, between the two extremes are all degrees partaking of both the nature of pure and applied research, so that there appears to be no well-defined line of demarcation between the two. There is need for both types of research in soil conservation work, but there is a greater immediate need for applied research in order that the conservation programs now under way be carried out economically, satisfactorily, and expeditiously.

An absorbing interest is essential to success in research, and interest together with training in fundamentals in any particular field of endeavor constitutes the important requisites of a good research worker.

I was particularly interested in the emphasis placed upon the need for satisfying the customer, which is perhaps seldom questioned in industrial research, but has not always seemed so apparent in agricultural research. In agriculture the field technician and the farmer are customers who must be satisfied, and unless they can see profit to the farmer in a research program they usually display little interest in the results.

I am heartily in accord with the statement that the research man should have close and unrestricted contact with groups in his own organization so that facts developed in one group may be available to the other groups. Not only does this result in an interchange of ideas that is mutually helpful, but it also avoids needless duplication with resulting waste of time and funds.

Discussion by Waldo E. Smith

Senior hydraulic engineer, hydrologic division, U. S. Soil Conservation Service

ONE of the most important aspects of successful research is the establishment of objectives. This presupposes the realization of an existing problem and the desire to solve that problem. It is not essential at the outset to trace the probable course of one's studies and thoughts from the present status of the situation to the solution of the problem. Sooner or later as the work progresses, a course or various courses for the solution will need to be charted, and this of course should take into account all previous work that bears on the problem. It is important that the objectives be kept in full view at all times.

One of the most difficult phases of research work is the proper integration of one's data to secure the desired solution. This requires vision and imagination which explains why good research workers are so scarce. One man may see great possibilities in data that dozens of others overlooked. It is, after all, the final analysis of accumulated data that is truly the research aspect of the work after the course to be pursued has once been charted.

While maintaining the objectives in full view, the experimenter must be constantly cognizant of the importance of "accidents", as suggested by Dr. Hayes. Occasionally, as he pointed out, an investigator working toward certain objectives may inadvertently discover some important item bearing on a related field which may, as in the instance of the discovery of radioactivity, completely revolutionize the thought in that field. The recent development of atom-smashing devices, the resulting possibilities of the tapping of atomic sources of energy, and the transmutation of elements, stagger the imagination.

Dr. Hayes mentioned the matter of duplication of work. To me it seems desirable that a certain measure of duplication exist inasmuch as it facilitates the checking or the disagreement of conclusions, and thus affords a measure of the probable objectivity of the investigation. For some time two schools of thought have

been struggling with opposing concepts of the cosmic ray, its origin and its nature. At times the resulting argument has very nearly obliterated a semblance of objectivity in the scientific studies. The fact that there was not concurrence on the part of eminent scientists working in the same field nonetheless is serving the useful purpose to intensify studies which we hope will be objective in their outlook and conclusions.

One of the things of which research workers should be constantly cognizant is the matter of applicability of their investigations. This is especially true of industrial research and research carried on by government bureaus for improvement in some particular field. Even under the most favorable circumstances there are likely to be barriers of various magnitudes arising between research workers and operations and production people who must put the findings to good use. The research worker is frequently charged as being impractical. All effort to maintain close working relations between the finders and the appliers is desirable.

We should not permit an opportunity to pass to challenge those who say that science is responsible for the present world chaos and disorder and has achieved great things in the manner of man's destruction. This challenge should be answered with a challenge to those workers in the social, economic, and political spheres to apply the same objective thought to the problems in their field that scientists are applying to matters in theirs. The fact that social, economic, and political developments have not kept pace with the developments in science, so that these developments could be used to the best interests of mankind, is no just criticism of the men of science. Let us hope and pray that the answer may soon be found so that man will be the master instead of the victim of his own scientific achievements.

Discussion by Deane G. Carter

Professor of agricultural engineering, University of Illinois

DR. HAYES indicates certain fundamental advantages of industrial research as follows: (1) The stimulation derived from large-scale activities close at hand, (2) the earning power of research by which it pays for itself, and (3) the closely knit relation of facilities in the larger units of industry that offer less danger of duplication, lost motion, and lack of stimulation.

Those of us in the agricultural experiment stations need not be concerned about the lack of stimulation nor about the direct earning power of the research, for problems are presented more rapidly than they can be solved, and the economic value of agricultural research is unquestioned.

There is often a lack of unity, however, that constitutes a valid criticism of station work. This has resulted principally from the departmental organization within the stations, and failure to effect full cooperation for a mass attack on problems.

Experiment station workers in agricultural engineering have sometimes contended that if the scientists in other fields could establish the *requirements* for any given situation, the engineer would be able to develop the machine, structure, or procedure to solve the problem. For a successful solution, however, the engineer cannot wait until other departments have set up the requirements, nor can any department alone undertake the responsibility of stating the requirements.

Much of the delay, duplication of effort, and apparent lack of agreement that occurs could be avoided through complete cooperation of every interest involved in the problem. For example, there have been differences of judgment regarding the requirements for the control and regulation of whole milk production, and the question is raised as to whether alternative solutions might not be as effective, but less costly, and more practical for the producer.

Authorities in housing have defined "minimum" requirements for dwellings that are beyond the financial abilities of one-half or more of the rural population.

Recently I have been associated with studies in grain storage in which four states are doing active work; the Bureau of Agricultural Chemistry and Engineering (USDA), and federal agencies as widely separated as the Agricultural Adjustment Administration and the Regional Research Laboratories are directly interested. Departments of agronomy, agricultural engineering, and entomology are working in cooperation on the details of this storage study. Recently it was found that some questions had been raised relative to the quality of stored grains in feeding, which involves departments of animal science.

The agricultural engineer is interested not only in the physical facts of the storage structure, but in the air movement, temperature control, fumigation, moisture condition, market grade, germination, insect infestation, and feeding value of grain. The sole purpose of the agricultural experiment station is to arrive at the truth, and find the best solution of problems. The answer is sooner found by the teamwork of all departments than by individual action.

Discussion by G. W. McCuen

Chairman, department of agricultural engineering, Ohio State University

RESEARCH problems are today becoming much larger in scope and are so interrelated that no one person or agency can hope to solve them all. The recognition of a problem usually begins with some difficulty or conscious need. Then we start thinking about it, and out of our thinking may come some coordinated procedure for the solution. Much of our research today, however, is wasted effort because of the lack of organized procedure. Again, we may have a somewhat selfish viewpoint toward our own field instead of lending all assistance to those in other fields who can contribute to the solution of a particular problem.

Much research involving engineering lies within the development or application stage, yet most of our engineering problems lie within the area of discovery. Again, because of the magnitude of most problems in agriculture, planning is an important responsibility of the research worker. Due account should be taken of the relationship of the cost of the work to its ultimate value. The cost of planning is small compared to the cost of actually carrying on the work, and since planning will contribute to the progress of the project, it should be done in all cases. Expense will be reduced if the work is laid out so the experiments are carried out in a logical order.

We should pay much attention to the qualifications of the research man. In addition to his training, he must be quick to recognize the truth. Since it is necessary for various specialists to work together on most of our problems, it is important to have men who can and will cooperate. Also, coordination of the work comes to naught if research workers do not cooperate to the end result.

A research worker must have a scientific curiosity and a creative urge. With this qualification he may discover small clues to important phases or results of a research project, and these may lead to far-reaching and unexpected results. In addition, he must be enthusiastic about his work and receptive to new ideas. In too many cases have preconceived ideas led the worker astray in his procedure. Also we find men who have a negative answer to everything suggested.

A research worker must also have ambition and diligence in his work. He must devote his whole attention to the activity at hand which requires mental as well as physical activity. For success in research there is no substitute for hard work through concentration. He must be willing to persevere and not become too easily discouraged.

He must also have a strong vivid imagination and show much ingenuity, particularly in those problems dealing with new products, new principles, or new processes. He must also hold a more or less practical viewpoint and have much common sense in solving problems. In many cases the personality of the research worker has not been given much consideration; however, it should be made an important qualification in the research worker.

Discussion by A. W. Clyde

Professor of agricultural engineering, Pennsylvania State College

AT AN A.S.A.E. meeting a few years ago, E. M. Mervine made a statement substantially as follows: "In the future we will attach increasing importance to the words, 'these results are significant' or 'are not significant' in reports of experimental work." He referred, of course, to statistical analysis of research data as a help in its evaluation. Statistical analysis is a well-accepted tool in the biological sciences such as those concerned with plants, soils, animals, and human beings. Perhaps we have lagged behind in recognizing its usefulness. We might accept it more readily if it could be given a name more easily pronounced.

As a very simple example, suppose we are studying the value of a rolling landside on a plow. Part of this study is the making of draft tests with both sliding and rolling landsides, much care being taken to have uniformity of depth, width, speed and other factors which can be observed. The following results are secured for five tests of each:

							Means
Sliding	—	1200,	1025,	1110,	1050,	1115	1100
Rolling	—	1100,	1030,	1000,	950,	1045	1025
						Difference....	75

We are often tempted to carry out the calculations to such a point that the difference is given as some such value as 74.9852 etc. A little thought will convince us that, in this case, figures to the right of the decimal point have absolutely no value. In fact, the 5 in the 75 is doubtful since dynamometers are not accurate to that degree.

In the past many of us have reported only the means (or

averages) and their difference. Such figures have some value but are often misleading. A person trained in statistics will want to know something about the figures which go into the averages. He will point out the difference of 175 in the first group and 150 in the second group, even though all conditions were supposed to have been the same in each group. We have to admit that these differences were caused by factors not under control. Evidently each test contains an element of chance; therefore, chance enters into any conclusion drawn from the tests. Obviously no result can be conclusive if chance enters into it, but there are various degrees of probability or the amount of chance. In this case it might be said that there are approximately 90 chances out of 100 that the rolling landside caused less draft, the reduction being 75 $\pm$ a standard error of 39. The remaining 10 chances are that the difference was caused by factors other than the landside. Such a result is not called significant. More tests are needed if we are to attain that degree of confidence in the conclusion.

The foregoing shows only one of the uses which can be made of statistical analysis when we are experimenting with things in which all variables are not controlled. We should at least know something of its possibilities. Only then can we judge to what extent we should be using this valuable research tool.

Discussion by Dr. H. J. Barre

Research agricultural engineer, Iowa Agricultural Experiment Station

DR. HAYES has mentioned the need for close and unrestricted contact with groups within the research man's own organization, and I should like to mention the need for close cooperation among research men working on the same problem or different phases of the same problem.

In agricultural research involving engineering, there are very few problems which are largely engineering. Many of the problems are complex, and often involve the combined efforts of the engineer with bacteriologists, pathologists, entomologists, agronomists and men trained in other fields. There is, of course, also cooperation with chemists, physicists, and mathematicians, but this is more often on a consulting basis rather than one of actual cooperation.

The success of cooperative research depends primarily upon the individuals, even more so than in the case where an individual conducts the primary part of the work alone. In addition to a mutual understanding of the problem and the objective to be accomplished, there must be complete confidence in each other. In order to establish confidence, the individual must be ready to work with others and be willing to share honors. Credit must be given where credit is due. The individual must be considerate of the views of his fellow cooperator and should be careful not to be too anxious to pass judgment upon the other man's results.

In other words, there must be teamwork. The men must be willing to "lay their cards on the table". Where this exists results are inevitable, and the "accidents" to which Dr. Hayes has referred are much more likely to occur.

Equipment for Subsurface Tillage

(Continued from page 46)

out in the Nebraska area. We have found that the farmer is more willing to try new methods if it doesn't cost too much, so we have some experimental equipment to use on a regular direct-connected lister. This lister is owned by many farmers at this time, so they would be required to buy only the additional tool bar and ground-working equipment.

Fig. 1 shows experimental subsurface tillage equipment, including a long tool bar, for a standard lister. Each spring-trip shank, equipped with a large 24-in subsurface tillage sweep, also is adjustable for the amount of power required to make the spring trip work; also, each shank is adjustable to give more or less suction to the sweep. The sweeps are bolted to the shank and are easily removed. Each of these beams are equipped with a large 20-in notched rolling coulter. This type of coulter will handle a large amount of straw and weeds, especially Russian thistle. As this is a power-lift type of lister, in making short turns it is raised out of the ground. The subsurface tillage equipment may be used on a pull-type lister, as seen in Fig. 2, which shows another type of lister. Fig. 3 is a regular field cultivator fitted with subsurface tillage equipment.

In conclusion, I believe there is plenty of need for more experimental work for all of us, whether we recommend that the farmer keep all straw and stalks on top of the ground for surface mulch, whether he sells it for a cash income, or whether he plows it under. I do not believe any one can say that there is only one way to handle all varieties of soil and crops, and so our recommendations should be based on sound, thorough research for each condition or locality.

Sound Service to Farmers

By Frank Hamlin

MEMBER A.S.A.E.

THE great task of the agricultural engineering branch of the engineering profession is to find the most effective ways and means of solving agricultural problems through engineering.

Because the farmer is the heart of all agricultural problems, we must know a good deal about him, what he wants and what he and others are doing to satisfy those wants. Deciding and delivering what we *think* he *should* want, regardless of what he *does* want, effectively solves no problem in agriculture.

Taking him in cross section, the farmer is a pretty substantial citizen. If you take the cross section of any other group, I doubt if you will find better basic material to work with. His feet are very much on the ground — not on a desk. He is self-reliant to a high degree, and he has a well-developed sense of social responsibility. The independence of his thinking is tempered only by his own practical experience. He is considerably above the human average in honesty. Witness the fact that in a recent period the company, which I represent, did one and a quarter million dollars worth of business with him at a net charge off for bad debts amounting to $97.20. Figure that loss on a percentage basis, and you won't find it matched in equally sizable dealings with any other group.

I think that we, who specialize in the multitudinous narrow crannies of the whole, broad mass that is agriculture, are all too prone to diagnose all agricultural ills as stemming from lack of attention to and appreciation of our own little bacteria-laden pits.

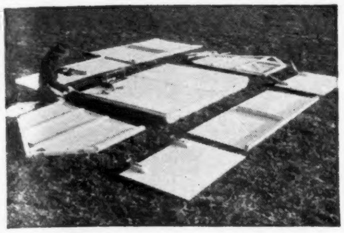
To be sure, we *must* specialize. If we don't, we shall be completely incompetent to serve the man we must serve, if we are to serve agriculture. But to serve him effectively, we must have at least a nodding acquaintance with the thousands of other specialties which go to make up the vast heap of agricultural knowledge.

That is what this and all other meetings of agricultural specialists are for primarily. Only by putting our individual nickels in the pot and by watching other nickels as they go in, can we hope to see our own or anybody else's nickel become a dollar.

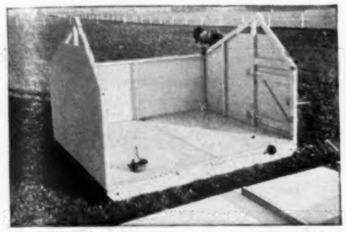
Few of us, *as individuals,* will revolutionize the ways of agriculture. But, *as a group,* with our collective eye always on what the man we are serving wants and on what other individuals and other groups are doing to satisfy his wants, *we can* make sound contributions.

(EDITOR'S NOTE: The foregoing are the opening remarks of Mr. Hamlin, as chairman of the North Atlantic Section of A.S.A.E., at the Section meeting at Jackson's Mill, W. Va., in October 1941. Mr. Hamlin is vice-president of Papec Machine Co.)

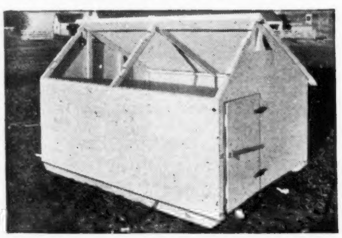
WHY PREFABRICATED FARM STRUCTURES HAVE SUCH AN IMPORTANT PLACE IN TODAY'S ECONOMY:



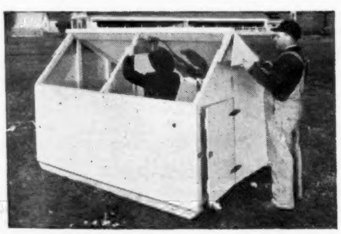
This prefabricated plywood hog cot is delivered to the farmer in sections. He lays them out for quick assembly. Because the



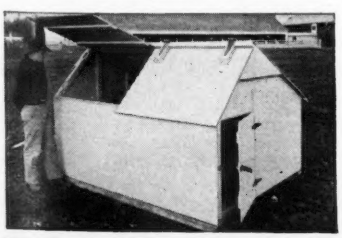
construction is light yet strong, he can assemble them without help. The shop-built sections fit tight, prevent drafts, pro-



vide clean, sanitary surfaces. The finished structure is portable and puncture-proof. It cannot be racked out of shape. If as-

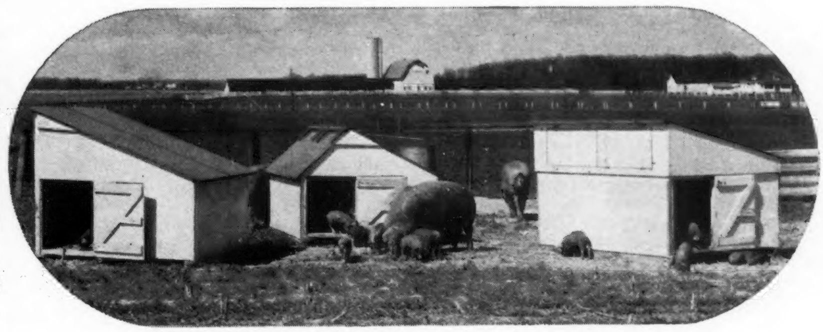


sembled with bolts or screws, this hog cot can be demounted for easy transportation to another place at a later date.



1. ***They help speed agricultural production . . . provide superior, labor-saving shelter.***

2. ***They offer a welcome source of income to many whose regular business is curtailed.***



Just published are plans for 8 hog and poultry structures that can be easily prefabricated with Douglas Fir Plywood!

● Prefabricated farm structures benefit both the farmer and their manufacturer . . . and, in turn, the nation.

They free the farmer from construction work for which he seldom has tools or skill. They not only give him a head start but enable him to devote his full attention to food production. Because he has the opportunity to study *completed* structures at his lumber yard or agency, he can determine the design best suited to his individual requirements. He gets a structure—if Douglas Fir Plywood is the basic material—that is superior, more comfortable, sanitary and economical than he could build himself from traditional materials.

The manufacturer may be the farmer himself—but usually in a better position to prefabricate farm structures are lumber dealers, builders, farm cooperatives, 4-H clubs, colleges and schools or other farm agencies. For once jigs are set up, the structures can be quickly built on a production line basis. This mass production not only brings down the unit cost and permits superior construction practices such as gluing, but also gives the manufacturer a new source of income that is vitally important if his regular business has been curtailed.

Just off the press are 2 Construction Bulletins on hog and poultry houses. They show representative agricultural college designs and various assembly methods. Send for free copies. You will find them interesting and useful in stimulating prefabrication and increased farm production in your territory. You are also invited to write us on problems relating to the use of Plywood in any agricultural production structure. Douglas Fir Plywood Association, Tacoma, Washington.

EXTERIOR-TYPE DOUGLAS FIR PLYWOOD should be specified for all farm structures that are permanently exposed to the weather. It is made with a water-proof bond and has proved durable under all conditions when properly finished. It is readily available, is easily worked with common carpenter tools, is lightweight and long-lived. It builds sanitary, comfortable, attractive houses and shelters of every type.

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NEWS

A.S.A.E. Meetings Calendar

April 3 - 4—Southwest Section, Texarkana, Texas.

June 29 - July 1—Annual Meeting, Hotel Schroeder, Milwaukee.

November 30 - December 2—Fall Meeting, Stevens Hotel, Chicago.

Farm Safety Conference

THE First National Home and Farm Safety Conference, under the sponsorship of the National Safety Council, will be held at the Stevens Hotel, Chicago, February 17 and 18.

The first session on farm safety will be held at 2:30 p.m., February 17, and feature the following subjects and speakers: Farm Accidents, by H. M. Pontious, Ohio Farm Bureau; Methods of Combating Safety Problems, by C. M. Seagraves, Illinois Agricultural Assn.; Engineering Aspects of Farm Safety, Dr. J. B. Davidson, Iowa State College; Ways of Interesting Farm Families in Safety, by E. W. Lehmann, University of Illinois.

Following this session a planning committee for the Farm Equipment and Engineering Section will be appointed, and this committee will hold a meeting at 7:30 p.m. the same day.

The Rural Homes Section will hold a session at 9:30 a.m., Wednesday, February 18, at which will be discussed the report of the planning committee of this section dealing with education, engineering, and promotion and direction of activity in connection with safety problems in farm homes. Concurrently there will be a session of the Farm Equipment and Engineering Section, presided over by Frank Kranick, which will discuss the proposed program submitted by the planning committee of the section.

Further information relative to the conference may be obtained from the offices of the National Safety Council, 20 North Wacker Drive, Chicago.

Soil Tilth Committee Proposes Broad Program

THE members of the Joint Committee on Measurement of Soil Tilth, a cooperative committee activity of the American Society of Agronomy and the American Society of Agricultural Engineers, held a meeting November 14 in Washington. Committee members present included Dr. L. D. Baver (committee chairman), director, North Carolina Experiment Station; Dr. M. L. Nichols, assistant chief, U. S. Soil Conservation Service; Dr. Robert M. Salter, U. S. Bureau of Plant Industry; Dr. S. J. Richards, soil physicist, New Jersey State College; Dr. B. T. Shaw, physiochemist, Ohio Agricultural Experiment Station; Dr. J. F. Lutz, associate in soils, North Carolina Experiment Station, and I. F. Reed, associate agricultural engineer, U. S. Bureau of Agricultural Chemistry and Engineering.

The discussions of the meeting dealt largely with the USDA Farm Tillage Machinery Laboratory at Auburn, Alabama, and at the outset was brought out by Mr. Reed that while the work at the laboratory was progressing satisfactorily, so far as making comparative measurements on the reactions of tillage tools was concerned, the staff, consisting of agricultural engineers entirely, realized the facilities of the laboratory were not being used to the fullest possible capacity, for the reason that soil physical and plant physiological relationships were not being taken into consideration along with the mechanical measurements being made. The general consensus of those participating in the discussion was that the laboratory might well be considered as a nucleus on which ultimate soils and tillage machinery research might be built, since it has the advantage of being located in a most favorable climate, also the equipment, laboratory facilities, and soils for a large part of such work.

In this connection it was brought out that state agricultural experiment stations are able to study thoroughly only a few points, usually with reference to their peculiar local conditions, and the opinion was expressed that state workers would doubtless welcome a laboratory beyond state borders with which they could cooperate or coordinate their work so as to make possible interpolation for conditions other than those under which their respective studies are made. It was thought that, if proper facilities were available, workers at a number of experiment stations could plan as a part of their project to spend some time at the Auburn laboratory, perhaps a few weeks in the winter, when cold weather would not permit work at their own stations.

This discussion led to consideration of what might be done to increase the facilities of the laboratory to enable the carrying on of complete studies of plant, soil, and machinery relationships that are deemed necessary. It was pointed out that greenhouses, air conditioning, additional soils laboratories, and additional floor space would be needed. Representatives of various agencies present indicated great interest in the proposed expansion and a willingness to cooperate in any far-reaching program of research that increased facilities would make possible. It was also suggested that plans for increasing the laboratory facilities might be developed as a project under the Public Works Administration.

The broad program to coordinate research activities comprising complete studies of plant, soil, and machinery relationships, envisioned at this meeting, and calling for the cooperation of agronomists and other specialists, as well as engineers, will be of particular interest to agricultural engineers and to the farm equipment industry, and it would seem to merit the generous support of all interested groups.

Pacific Coast Section Officers

AT THE business meeting of the Pacific Coast Section of the American Society of Agricultural Engineers held at Davis, Calif., January 9, the officers for the ensuing year were elected: *Chairman,* Dr. O. W. Israelsen, professor of irrigation and drainage engineering, Utah State Agricultural College; *First Vice-Chairman,* J. E. Christiansen, assistant irrigation engineer, University of California; *Second Vice-Chairman,* O. W. Sjogren, agricultural engineer, Killefer Mfg. Corp.; *Third Vice-Chairman,* R. A. Work, associate irrigation engineer, U. S. Soil Conservation Service, and *Secretary-Treasurer,* W. W. Weir, drainage engineer, University of California. M. R. Huberty, University of California, was elected a member of the executive committee of the Section, the membership of which includes also the five officers just named. The nominating committee elected by the Section includes George Hardman, state coordinator, U. S. Soil Conservation Service; S. W. McBirney, associate agricultural engineer, U. S. Bureau of Agricultural Chemistry and Engineering, and P. C. McGrew, assistant regional conservator, U. S. Soil Conservation Service.

New Tennessee Section Officers

AT a recent meeting of the Tennessee State Section of the American Society of Agricultural Engineers, held at Knoxville, the following officers were elected: *Chairman,* J. H. Nicholson, assistant chief, watershed protection division, Tennessee Valley Authority; *vice-chairman,* Ira L. Knox, assistant electrical engineer, division of electrical developments, Tennessee Valley Authority; and *secretary-treasurer,* G. E. Henderson, associate agricultural engineer, Tennessee Valley Authority.

Personals of A.S.A.E. Members

George A. Crabb, Jr., was recently promoted from the classification of assistant engineering aide to that of junior soil conservationist in the U. S. Soil Conservation Service. He is stationed at CCC Camp SCS-Ga-13, Cartersvlle, Ga.

Dale I. Cronkhite is now employed as development engineer with the Goodyear Tire and Rubber Company at Akron, Ohio. He formerly held a position as junior civil engineer in the U. S. Soil Conservation Service. His present address is 1019 W. Exchange Street, Akron, Ohio.

J. W. Martin, instructor in agricultural engineering, Kansas State College, and *June Roberts,* formerly instructor in agricultural engineering at the same institution, and now investigator, Washington C.R.E.A., are joint authors of Extension Bulletin 87, entitled "Feed Grinding with Small Electric Motors", bearing the publication date of September 1941 and issued by Kansas State College.

J. C. Wooley, W. M. Clark, and *R. P. Beasley,* respectively, head of the agricultural engineering department, extension agricultural engineer, and research instructor in agricultural engineering, University of Missouri, are joint authors of Bulletin 434, entitled "The Missouri Soil Saving Dam", recently issued by the Missouri Agricultural Experiment Station. Messrs. Wooley and Beasley are also joint authors of Circular 213, entitled "The Appraisal of Farm Buildings", recently issued by the same station.

Agricultural Engineering Digest

A review of current literature by R. W. TRULLINGER, assistant chief, Office of Experiment Stations, U. S. Department of Agriculture. Copies of publications reviewed may be procured only from the publishers at the addresses indicated.

AGRICULTURAL ENGINEERING INVESTIGATIONS AT THE MICHIGAN STATION. Michigan Agrl. Exp. Sta. (East Lansing) Bien. Rpt. 1939-40, p. 6. This report briefly discusses work on tests of a new four-wheel tractor, losses in potato storage from different handling methods, and farm efficiency with reference to farm equipment. (coop. U.S.D.A.)

BEECH: ITS PRODUCTION, PROPERTIES, USES, SEASONING, AND TREATMENT, *R. J. Hoyle, H. L. Henderson, J. O. Blew, and N. C. Brown.* N. Y. State Col. of Forestry, Syracuse Univ., (Syracuse) Bul. 13 (1940), no. 3, pp. 76, figs. 24. Part 1 deals, in part, with the general characteristics of trees and logs, production, structure, properties, characteristics, machining and behavior characteristics, early uses of beech, uses of beech in industry, and uses of beech in construction. Part 2 takes up air seasoning and kiln-drying of beech. With respect to air seasoning it is concluded that beech sapwood will dry without surface checking and splitting at almost any season of the year and will dry much faster than heartwood at any season, reaching 20 per cent moisture in about from 2 to 3 weeks in summer and from 8 to 10 weeks during the winter. Heartwood of beech surface checks readily, but if its rate of drying can be held down to 1 per cent loss a day either by a humid atmosphere or by close, protected piling, no surface checking will result. Surfaces of boards exposed to direct sun will start surface checking in from 24 to 48 hr. When beech lumber reaches 15 per cent moisture content any surface checking is largely invisible as the checks have closed by internal shrinkage. Warping and cupping are not pronounced in air-seasoned beech if care has been exercised in piling.

The kiln-drying experiments showed that 1-in beech lumber can be kiln-dried without any appreciable amount of surface checking in from 14 to 16 days; the 2-in beech lumber in from 36 to 38 days. In drying green beech the relative humidity must remain above 90 per cent for about one-third of the drying period if surface checking is to be prevented. The optimum rate of drying of 1-in lumber is 4.5 per cent per day; of the 2-in lumber, 1.6 per cent per day. Intermittent steaming is beneficial in the prevention of severe case hardening strains and seems to prevent excessive warping. Most of the surface checking of air-seasoned beech will surface out during manufacture if the kiln-drying has not deepened the checks. Beech squares and other small dimension will dry under the same drying schedules as lumber but faster.

Part 3, on the preservative treatment of beech, brings together service records from various sources. From these, and other information presented, it is concluded that, for use as cross ties, this wood has demonstrated a superiority over other creosoted woods, more frequently selected for this purpose. Because beech is readily available in New York State a potentially large market exists for the two products mentioned above. It is estimated that over 800,000 cross ties and more than 10,000,000 fence posts are required in this State each year to replace those no longer fit for service. With preservative treatment beech should fill a large part of these requirements. Creosoted beech highway posts should give at least 30 years' service, and on this basis should result in lower annual costs than either steel or concrete.

EFFICIENCY OF THE COMBINED HARVESTER-THRESHER FOR GRAIN SORGHUMS AND FACTORS INFLUENCING THE QUALITY OF WHEAT DURING FARM STORAGE. (Partly coop. U.S.D.A.) Kansas Agrl. Exp. Sta. (Manhattan) Bien. Rpt. 1939-40, pp. 55-57. The work here summarized consisted mainly of storage studies, by F. C. Fenton, indicating no ventilation to be needed for 12 per cent moisture grain, ventilated bins much better for moderately damp material, and ventilation methods to show an effectiveness diminishing in the order (1) power fans, (2) wind-pressure cowls, and (3) wind-suction cupolas; and a study of the influence of time, temperature, moisture, and air supply on the quality changes in wheat, by Fenton and C. O. Swanson.

AGRICULTURAL ENGINEERING INVESTIGATIONS AT THE WYOMING STATION. (Partly coop. U.S.D.A.) Wyoming Agrl. Exp. Sta. (Laramie) Bul. 243 (1941), pp. 7-8, 41, fig. 1. This report notes the furrow drill as a means to a greatly increased certainty of winter wheat production; the use of pitting machines, including especially an eccentric one-way plow, to prepare summer fallow in such a way as to double the yields which follow the use of the common moldboard plow; and the manufacture by implement makers of large quantities of the disks required for this special plow. A study of the waste of irrigation water under various applications is also noted. *(Continued on page 70)*

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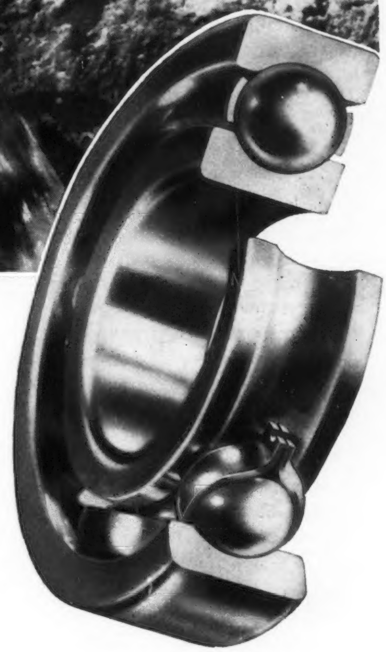

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The farmer who owns this Johnston Pump must have a deep sense of satisfaction in the thought that this unit works year after year without bearing trouble. Back of this satisfaction are SKF Deep Groove Ball Bearings assuring the same dependability on the vertical shaft of this pump that you find in SKF's on giant bombers, deadly guns, powerful battlewagons and hardy tanks. It is important that Agriculture, in doing its share for National Defense, is doing it with SKF-equipped machines.

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BALL SKF BEARINGS

Agricultural Engineering Digest

(Continued from page 68)

Agricultural Engineering Investigations at the California Station. (Partly coop. U.S.D.A. and Colo. State Col.) California Agrl. Exp. Sta. (Davis) Bien. Rpt. 1939-40, pp. 15, 16-17, 129-137. This report notes work on Imperial Valley drainage, flood-control studies, forest influence on mountain watersheds, sugar-beet machinery, a rubber-roller bean thresher, rubber-roller flax harvesters, orchard-heating experiments, air-conditioned greenhouses, new soil fumigant applicator, pest-control equipment, water requirement of crops, new irrigation equipment, land preparation for irrigation, evaporation of water from soils, and portable-sprinkler systems.

Agricultural Engineering Investigations at the Iowa Station. (Partly coop. U.S.D.A.) Iowa Agrl. Exp. Sta. (Ames) Rpt. 1940, pt. 1, pp. 26-28, 55-64, 147-149, figs. 3. These have included soil and water investigations on the soil conservation experimental station in Page County; investigation of farm-building losses due to wind and fire, utilization of clay products in farm-building construction, atmospheric exposure tests of wire and fencing, utilization of plywood in farm-building construction, utilization of steel in farm-building construction, utilization of lumber in farm-building construction, and farm-fence construction, all by H. Giese; agricultural engineering service, directed by J. B. Davidson; work on utilization of agricultural wastes for farm-building insulation, by H. J. Barre; design, development, and trial of a two-way terracing machine, by E. V. Collins; a study of the efficiency and economy of pneumatic tires for transport wheels on agricultural equipment, by E. C. McKibben; and hill-culture studies (for conservation and erosion control) in Iowa, by J. M. Aikman.

A Study of the Physical Characteristics of Soils, with Special Reference to Earth Structures, *D. M. Burmister*. Author (New York), 1938, pp. V+63, figs. 23. The author brings some of the physical factors into a more unified and consistent pattern by an evaluation of the grading analysis of soils, based on physical as well as simplified statistical considerations. He points out that the grading-density relations of granular materials describe basic physical relations and give quantitative expression to the important influence of the distribution of particle sizes and of particle shape upon density, and that these relations are of fundamental importance, because density is a determining factor in the supporting capacity of the natural soil and in the stability of slopes and earth fills of granular materials.

The plastic characteristics of fine-grained soils are treated in a similar manner to define reliable relationships between the simpler soil tests and those describing the behavior of soils. Certain practical applications in the analysis of soils for earth dams are made, and methods developed for the analysis and presentation of the data are discussed.

A Conveyor for Handling Potatoes, *E. J. Wheeler, F. Linebaugh,* and *C. H. Jefferson.* Michigan Agrl. Exp. Sta. (East Lansing) Quart. Bul. 23 (1941), No. 3, pp. 164-168, figs. 2. The authors describe an elevator consisting of a belt conveyor, a hopper, and a carriage which serves both to regulate the height of the belt and to make the unit portable. For a new belt a two-ply 16-in canvas belt may be obtained at a cost of approximately 50c a lineal foot. The authors used a part of a rubber belt salvaged from a large industrial plant. The maximum length of conveyor was found to be about 16 ft if driven from a motor mounted on the lower end. The belt is tightened by an adjustable 4-in roller at the top end, travels at the rate of about 120 ft per minute, and is driven by a 4-in roller wrapped with rubber belting at the bottom. The 4-in steel roller is to provide additional friction, which is desirable to prevent the conveyor belt from slipping. To overcome any tendency of the potatoes to roll backwards, 15-in lengths of 1-in garden hose are attached to the belt from 12 to 15 in apart.

Such an elevator was found to effect a light saving in shrinkage loss and a very large saving of time. A slatted-bottom hopper which forms part of the machine described was found to remove about 1.5 lb of dirt per bushel of potatoes handled. Working drawings accompany the article.

Agricultural Engineering Work at the South Carolina Station. South Carolina Agrl. Exp. Sta. (Clemson) Rpt. 1940, pp. 20-22, 39-47, figs. 3. This included nonpressure preservative treatment of southern pine posts, by G. H. Dunkelberg, G. B. Nutt, H. T. Polk, and A. R. Reed; farm-machinery demonstration, by W. N. McAdams and C. S. Patrick; and use of electricity in curing and storing sweetpotatoes, and further studies of electricity in sweetpotato plant production, both by J. B. Edmond and Dunkelberg.

New Literature

"SOILS AND FERTILIZERS," by Dr. Firman E. Bear, professor of agricultural chemistry, Rutgers University. Third edition. Cloth, 6x9 in, 380 pages, 58 figures. $3.50. John Wiley and Sons, Inc., New York. The purpose of this book is primarily intended to acquaint students with the application of those scientific facts and principles useful in planning constructive systems of soil management and increasing the productive capacity of soils; it is intended primarily for use in beginning courses in soils in agricultural colleges. The book has been thoroughly revised for the third edition, and some additional contents have been introduced. Chapter headings include the following: Factors Affecting Crop Growth, Nitrogen and Mineral Requirements of Crops, Water Requirements of Crops, Origin and Classification of Soils, Chemical Composition of Soils, Biological Processes in Soils, Physical Properties of Soils, Water in Soils, Air in Soils, Soil Solution, The Control of Soil Water, Mechanical Improvement of Soils, Supplying Organic Matter, Rotating Crops, Nitrogen, Mineral, and Limestone Economy in Soils, The Livestock System of Farming, Soil Sanitation, Controlling the Soil Reaction, Nitrogen, Phosphoric Acid, Potash, and Mixed Fertilizers, the Selection and Application of Fertilizers.

EMPLOYMENT BULLETIN

The American Society of Agricultural Engineers conducts an employment service especially for the benefit of its members. Only Society members in good standing may insert notices under "Positions Wanted," or apply for positions under "Positions Open." Both non-members and members seeking to fill positions, for which ASAE members are qualified, are privileged to insert notices under "Positions Open," and to be referred to members listed under "Positions Wanted." Any notice in this bulletin will be inserted once and will thereafter be discontinued, unless additional insertions are requested. There is no charge for notices published in this bulletin. Requests for insertions should be addressed to ASAE, St. Joseph, Michigan.

POSITIONS OPEN

AGRICULTURAL ENGINEER wanted for farm structures research work in the agricultural experiment station of a southeastern college. Only a man with some research experience and not subject to immediate military service will be considered. Work will be primarily concerned with storage buildings. Good fundamental training with good scholastic records necessary. Salary up to $2,700 according to qualifications. PO-134

POSITIONS WANTED

AGRICULTURAL ENGINEER, also farm and supply manager, has had 20 years' experience in agricultural pursuits as manager of large farming enterprise and agricultural supply house, and as chief agricultural engineer of large irrigation development in the West. Has had technical training and practical experience in all phases of engineering and agricultural production, development, and marketing. Best of references. Forty-four years of age. Married. PW-341

AGRICULTURAL ENGINEER with 15 years' experience in the farm equipment industry; knows both farmer and tractor and implement industry in all sections of world; especially Canada and U.S.; advertising, public relations, editorial, camera, radio; can direct a complete service for dealers and factory; knows governmental and agricultural college officials; Farm Bureau; boys' and girls' clubs, livestock and special crop associations. Will locate anywhere the right firm or industry may wish. Have production records that speak. Personal portfolio mailed on request. PW-343

AGRICULTURAL ENGINEER desires employment offering larger opportunity. Ten years' experience in the electric utility industry and two years' experience as an assistant extension agricultural engineer. Good farm background. Particularly qualified to handle all phases of rural electrification, pump irrigation, and farm machinery. Capable of planning and conducting educational or promotional activities. Holds a state professional engineering certificate. Thirty-six years of age. Married. References on request. PW-344

AGRICULTURAL ENGINEER with B.S. degree from midwestern college (1938) and M.S. degree from southern college (1940), desires employment with the Soil Conservation Service, in a defense industry, or in other engineering work. Has 1½ years' experience as engineer with the U. S. Soil Conservation Service in the South and in the Pacific Northwest. Familiar with agriculture in most parts of the United States. Civil Service rating as junior engineer. Eligible for reappointment. Age 35. Married. PW-345